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History of the Development Of Chicago Pavements

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HISTORY OF THE DEVELOPMENT

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— INTRODUCTION —

"At the beginning of the century 24,000,000, of the population of the United States living in cities of 8000 and over had invested approximately $850,000,000 in improving their streets with curbing, paving, grading and sidewalks. Each year a further improvement of over $70,450,000 for such improvements and their care and renewal is made, and the amount is constantly increasing. But one other class of engineering works exceeds this in magnitude, that of the steam railway system in the United States". With the foregoing remarks, Mr. John W. Alvord opens his report to the Commercial Club of Chicago on the street paving problem of that city. A study of the expenditures made from year to year in street improvements in that city discloses the fact that, in spite of the enormous amounts of money spent in street improvements that city still remains behind other large cities in the percentage of improved streets. The amount of work done is hardly adequate to care for the needed replacements, so that the increase in percentage is small although the mileage improved each year is very great. At the

close of the year 1903 the total mileage of streets and alleys aggregated 4186.98 miles, and of this amount but 1398.96 miles were improved. Of this total improved roadway 1278.93 miles represented streets. Pavements that have long been out of repair, are included in this total, so that the real mileage of improved streets is far less than the figures would indicate. This apparent lagging behind is not due to a lack of public spirit in improvements but because up to within the last few years, cedar block pavements formed close on to fifty percent of the total, and the rapid deterioration of these in the more populated sections of the city has necessitated the replacement of these as an immediate necessity to the neglect, or rather postponement, of improvements in the less populated portions of the city. For instance, at the close of 1900 – 56.59% of the total pavement mileage was cedar block, while at the close of 1903 such pavements formed 47.42% of the total improved.

There is much to be done in Chicago in street improvements. When it is remembered that 80 miles of pavements were laid in 1904 at a total expense of $3,581,083.00 to the tax payers the importance of the work is all the more impressive. In the next few years every cedar block pavement will have to be replaced by some of the more modern and sanitary

forms, while the mileage of unimproved streets which demand attention with the rapid spread of population to the less dense sections of the city add to the importance of the problem. Such a condition of affairs affords a problem demanding the best judgment to produce the most economical results.

It was with a view of the importance of the pavement problem in Chicago that the writer undertook to trace the introduction of each of the principal kinds of pavements now used in that city and to draw such conclusions as the experiance with each form justifies.

Early Improvements.

In advance it may be well to give a short sketch of the early street improvements in Chicago. The town of Chicago was incorporated in 1833 and one of the first official acts of the trustees was an order given to the surveyor to "pitch" South Water Street from the United States reservation to Randolph St. on or before April 1834. The law in those days was peculiar in its working. The street commissioners were given authority to call upon all male citizens between the ages of twenty one and sixty years to work upon the streets and bridges three days per annum. This power operated over a territory one mile from the center of the town limits.

All the earlier street improvements consisted in turnpiking and grading and making such drainage improvements as would carry all water to the south branch of the river. South Water and Lake Streets were then the principal thoroughfares and were given immediate attention. In 1837 a most extensive piece of improvement was made by Hiram Pearson when he commenced the improvement of his north division to Chicago. This improvement involved the clearing, grubbing and grading of 14½ miles of street including Market St., Franklin St., La Salle St., Clark St., Chicago Ave., Dearborn St., Union St., Desplaines St. and a number of others north of the river. The grading of streets continued in a more or less crude manner till 1849 when the first plank road was laid. The work was rather ordinary in character yet, when it is remembered that the city was couched in a swamp, such street improvements were a boon to traffic. Yet the records tell us that the work of planking amounted to "less than nothing". The heavy traffic which confined itself to those pavements soon broke up the planks.

Planks were principally used till 1856 when a Mr. De Golyer laid what was then known under his name, a stone pavement which was virtually a cobble stone pavement. The popular verdict was

that it gave general dissatisfaction. However these pavements had some warm advocates and their existance gave rise to an intense interest in paving. Discussions arose among the advocates of planking macadamizing and cobble stoning. Some pavements of stone were laid but it was not till the fall of 1857 that the "Plankers" were defeated by the advocates of the macadam system. U. S. Bouton the city superintendant presented a report in August of that year showing that the first cost of laying macadam was less than that of planking the streets with 3" oak lumber; and this report tolled the death knell of the old plank road system.

Territorial Growth

From its incorporation as a town in 1833 to 1888 the territorial growth of the city was not very rapid. Up to the close of 1887 and after what is known as the "sixth annexation", the area of the city was 43.81 square miles with a total street mileage of 756.57, of which 381.89 miles were improved, approximately 50% of the total. In 1888 the annexations of the towns of Hyde Park, Lake, Lake View, Jefferson and a portion of Cicero increased the area to 169.88 square miles; and the street mileage increased to 2047.28 miles of which but 578.15 miles were

improved, representing 28% of the total. In 1890 the area was again increased by the annexation of Gano, Calumet, West Roseland, Fernwood, and Washington Heights, making the total 180.14 square miles. These latter additions brought the street mileage up to 2235.71 of which 668.49 miles, or 29.9% were improved. The above data is given to show the rapid increase in the street mileage in a comparatively short time. The figures are all the more significant in dealing with the paving question when it is remembered that these additions to the city did not include any hard surface pavements other than macadam, and that of a character only adapted to the traffic common to suburban districts.

Wood Pavements

The first wood pavements constructed in Chicago were laid in 1849, sixteen years after the incorporation of the town. In speaking of the street improvements in Chicago in his history of that city Mr Bross says:- "Our first efforts at paving, or one of the first, was to dig down Lake Street to nearly or quite on a level with the lake and then plank it. It was supposed that the sewerage would settle in the gutters and be carried off, but

the experiment was a disastrous failure, for the stench at once became intollerable. The street was then filled up and the Common Council established grade from two to six or eight feet above the natural level of the soil". We see from the above quotation that the conditions for good paving were not very favorable at that time; and it was not till 1857 that the street grades were brought sufficiently above the lake level to make good surface drainage possible

Prior to the laying of planks in Lake St. attention had been called to the utter uselessness of laying stone pavements on a surface which was not dense enough to carry a hard material. It was argued that it was unprofitable to invest in a pavement which would sink out of sight in one or two years. Moreover the success of plank roads in Canada and New York was convincing argument for its introduction in Chicago rather than stand the expense of the supposedly uncertain stone pavements. Accordingly the principal streets of the city were planked during the years 1849 and 1850. Among these were Madison, State, Clark, La Salle Wells, Market, and Randolph Streets.

Introduction of Blocks

As late as 1859 planks were

still used in the principal streets though the public verdict previous to that date was not favorable to their further use. The low grade of the streets made drainage poor, the heavy traffic soon broke up the planks and the rain water which lodged in the crevices caused the flying pieces of the planks to dash the foot passengers with mud. An improvement in wood pavements came in 1856 when Mr. S. S. Greeley laid the first Nicholson pavement in the city, on Wells Street between Lake and So. Water Sts. Its use in Chicago marked the first appearance of Nicholson block in the west. This stretch of pavement, amounting to 800 square yards, was completed in July 1857 at a cost of $2.30 per yard. Another section of this form of pavement was laid in Washington Street soon after. Nicholson blocks and Macadam became the popular forms, and with their introduction the improvements of streets was more general so that at the close of 1859 there were 15 miles of pavement in the city.

Substitution of cedar for Pine

The pine blocks used in the Nicholson pavements continued to be laid in increasing amounts until 1875, when cedar blocks were substituted for the pine; and from that date to 1882 upwards of 66 miles of cedar

block pavements were laid. Adding that mileage to the Nicholson block pavements, the city had 143.24 miles of wood block pavements out of a total of 183.66 miles of improved streets; 78% represented wood block at the close of 1882. The city also had a street mileage of 651 at that date so that its improvements represented but a small part of roadways available for traffic. Cedar blocks became the popular form of pavement for the less important business streets. Their comparative cheapness and freedom from noise under traffic, as well as the lack of dust where tolerably well maintained, made them ideal for the conditions of traffic met with in such streets. Moreover the law in those days required that the entire assessment of cost be paid at once. This condition coupled with the fact that the great fire of 1871 imposed burdens upon the people, rendered the consideration of a more permanent form of pavement out of the question. Property owners looked to a form of pavement cheap in first cost and yet possessing the qualities of a hard and clean pavement. In speaking of the effects of the fire on public improvements, the Board of Public Works in 1875 reports:- "Until greater relief is felt from the losses of the great fire and the

financial stringency which has prevailed since the panic, it will be almost impossible to induce the use of better and more durable pavements unless our laws can be so ammended as to permit the cost to be paid in several annual installments".

In spite of the large amounts of cedar block laid each year the results were not very encouraging. The property owners considered first cost its redeeming feature, the city authorities on the other hand considered it an inferior pavement. In his report for the year 1879 Chas. S. Waller then Commissioner of Public Works says:- "The cheap and short lived wooden pavements of the city are a species of shoddy that should not be encouraged. Cheap only in first payment - in the long run when aggregated they are, in my opinion, the dearest and most unsatisfactory pavement the city has ever used". The following year 80% of the pavements laid were cedar blocks. This crusade against the cedar blocks continued from year to year but of little avail. The property owners could not be educated in the economy of the harder forms of pavements then more commonly used, stone blocks and macadam. The excessive first cost of the former together with its noisiness, made it an undesirable form on the less trafficed busi-

-ness streets and on "streets which were of a semi residence character. The latter was a dusty road-way and, with the maintainance then given to pavements, did not appeal to the property owners very strongly. Moreover macadam even in its best forms could not be adapted to streets of a business character much less to streets with car rails in them. For streets of that nature there was but a choice between wood block and granite block; and the excessive cost of the latter resulted in the adoption of cedar block.

At the close of 1880 the streets in Chicago amounted to 651 miles of which 142.44 miles were improved; and of those improved 116.40 miles represented wood block pavements. No amount of persuasion on the part of city officials could counteract the preference for cedar blocks. Each year the Commissioner of Public Works offered arguments for the adoption of more permanent and sanitary pavements but the spread of the population and the need of improvements in the new living districts, called for a pavement cheap in first cost. Perhaps no Commissioner was a more ardent advocate for the abolition of wood pavements than Dewitt C. Cregier. His report for the year 1883 brings forward the merits of stone and macadam

pavements. In commenting on the amount of wood pavement laid up to that year he says:- "More than 3/4 of all our pavement is wood. It appears therefore that in the matter of street pavements, Chicago is an exception to the rule governing this class of improvement in most of the large cities of this country". He quotes from the reports from the cities of Brooklyn, New Haven, Cincinnatti, Washington, St. Louis and Milwaukee in justification of his attitude toward cedar blocks and continues;- "While wood block pavements have some temporary merits,- for instance, when it is new it is smooth, noiseless, pleasant to drive on, and when covered with gravel affords a good footing for horses; but these conditions continue in this city an average of only three or four years on our principal thoroughfares and while the street may not be repaved in seven and eight years, yet in from four to six years the pavement is generally so far gone as to be shunned by the public. The objectionable sanitary features of wood block pavements have been carefully considered by men of eminence in this country and Europe. A distinguished professor of hygiene at Montpelier France says:- 'the hygienist cannot look favorably upon a street covering consisting of a porous substance capable of absorbing organic matter and by its own

decomposition, giving rise to noxious miasma which, proceeding from so large a surface, cannot be re-garded as insignificant. I am convinced that a city with a damp climate, paved entirely with wood, would become a city of marsh fevers". General Gillmore says:- "The joints of wood block pavements constitute fully one third of its entire area, and under the average care the surface of filth exposed to evaporation covers three fourths of the entire street. The foul organic matter composed largely of urine and excrement of different animals is held in these joints, ruts and gutters where it undergoes putrefaction in warm damp weather and becomes a fruitful source of efflu-vium, or it floats in the atmosphere and penetrates the dwellings in the form of unwholesome dust irritat-ing to the eyes and poisonous to the organs of respiration"." Mr Cregier emphasized the importance of the pave-ment problem which confronted the city then and urged the consideration of forms of pavement which eliminate the sanitary objections to wood block.

Decline in demand for wood block

As is shown in table I wood block continued to be laid in large percentages of the total each year until 1889 when the percentage was 58 of the total amount of paving laid that year. This sudden

decrease was undoubtedly due to the legislative act passed that year which provided for the payment of special assessments in installments thus giving the property owners the relief referred to in the report for 1875 and won over more advocates for a better form of pavement. That year a large amount of macadam was laid. Between 1890 and 1895 the percentage of wood block pavements laid for the year varied between 75 and 59 though cedar block was gradually declining in popular favor. The annexations to the city occuring in 1889 increased the street mileage to 2047.28 miles of which 578.15 miles were improved; and of the latter amount 342.59 miles represented cedar block pavements. The introduction of brick and asphalt pavements in more than experimental amounts during the period from 1894 to 1900, and the relief secured by the payment of improvements in five annual installments, marked the fall of cedar block. The people were now better able to bear the expense of a more permanent pavement all all repavements were made with either of these two forms in the semi business and residence districts, though much macadam was laid in the latter. The average price of these pavements in 1893 were, Cedar block \$1.12, Macadam \$0.90 and Sheet asphalt \$2.80 per square yard. Now obsolete cedar

block improvements have become is attested by the percentage laid since 1900. In that year but 15 percent of the whole amount laid was cedar block, in 1902 - 3.8 percent while in 1904 the only wood block pavement laid was a creosoted block.

CONSTRUCTION

The early Nicholson pavements were laid upon a plank foundation, generally of hemlock. The foundation planks rested on pine stringers one inch thick and from six to eight inches wide and spaced eight to ten feet apart. Between the stringers there was spread a layer of lake shore sand flush with the top of the stringers so that the hemlock planks had an even bearing from stringer to stringer. The planks were laid lengthwise of the street. Upon these the pine blocks, 8"x4", were laid. Then a very fine gravel was spread over the surface of the blocks to fill the joints. After sweeping the gravel over the surface to thoroughly fill the joints the surface was cleared of gravel and washed with tar. The tar was applied while hot by means of a sprinkler arrangement, the pouring spout being so made that the issueing tar took the shape of a thin sheet rather than a spray. While the tar was still soft a layer of gravel was

thrown over the surface and the pavement was ready for traffic.

Cedar Block Pavements The introduction of cedar block brought no material change in the method of construction with the exception of the manner of filling the joints. The round blocks produced larger joints and consequently a courser gravel was used and rammed between the blocks after successive sweeping of gravel over the newly laid blocks, by means of steel rods one inch in diameter, and slightly tapered for six inches from the ramming end so that the rod could more readily work into the joints. After sufficiant gravel had been rammed in the joints to bring the filling flush with the surface, the latter was cleaned of all gravel and washed with hot tar. Upon the tarred surface was spread a layer of fine gravel and the street was ready for use.

LIFE OF CEDAR BLOCK PAVEMENTS.

The experiance with wood block pavements in Chicago indicates that the average life of the pavement is seven years. During the first three years under an average traffic of say 100 tons per sq. yd. per day, it makes a smoothe pavement, pleasant for driving and is comparatively noiseless. With the covering of gravel it affords a good foothold

for horses under all conditions of weather. This condition, however, does not last more than four years. After that age the pavement is usually so far gone as to be avoided by traffic as much as possible. The broomed top of the blocks, each presenting an arched surface, add to the tractive resistance and driving becomes very disagreeable even at a gait slightly better than a walk.

There is no data available as to the exact life of this form of pavement in terms of the tonnage traffic per year. Chicago like other cities of the country, has not carried on any tests to determine the economic advantages of the different kinds of pavements along the lines suggested by such experts as S. Whinery and G. W. Tillson; nor has the maintainance been adequate to supply the necessary constants entering into such a consideration of a pavement. In the year 1896 the amount spent in the repair of improved streets was \$196,306.39. Let us assume that all this was spent on the wood block pavements. In that year there were 752.68 miles of cedar block pavements, 63½ percent of the total. There was then spent on each mile an amount equal to $\frac{196306.39}{752.68}$ or \$2.60. Now it is safe to assume that this amount was not spent or applied to the total but rather to a

fraction of the wood pavements, say one eight of the total, which needed immediate attention to care for the traffic. Then there was spent on such streets $8 \times 2.60 = \$20.80$ per mile; and to bring the expense down to a more convenient unit we will assume that the roadway is thirty one feet wide. With such a width and neglecting the intersections the expenditure per square yard was $\frac{20.80}{31 \times 5280} = \$.00114$, an insignificant amount and if really representing actual conditions it would indicate a high class of pavements, and in no need of replacement. Those familiar with the wood block pavements in the city at that time and during the subsequent years know that the amount expended in repairs did not begin to approximate the needs. An interesting report is made by Commissioner of Public Works, Mr. McCarthy in 1894 in comparing the maintainance charges in Chicago with those in European cities. He says:- "the appropriations for 1888 allowed three cents per square yard for maintainance while in 1894 it was cut to one cent per square yard. In contrast with this, the amount set aside in European cities for maintainance range from eight to nineteen cents for wood, ten to seventeen cents for asphalt, four to twelve cents for brick or granite, and twelve to sixteen

for macadam, and it must not be forgotten that in the cities of the old world, street foundations are firmly set concrete and maintainance is concerned mainly with repairs to the wearing surface only. In this city for the boulevards under the control of the South Park Board, thirteen cents per square yard is devoted to the maintainance of avenues upon which only the light-est travel is permitted".

TREATED BLOCK PAVEMENTS

The objectionable features of cedar block pave-ments, their short life even under conditions of min-imum traffic and large joint space which affords lodgment for all kinds of offensive matter after a few years of their age, have directed attention to a form of pavement made of treated blocks known under different names according to the manner of treatment. Authorities who have had any experiance with these in a pavement regard them a sanitary form of paving material, and equal to any form of material for paving purposes in point of durability with the possible exception of granite block. The success of treated blocks in Paris and London where renewal was necessary only after traffic had so worn the blocks as to make driv-ing over them disagreeable, and where the weather seemed to show no deteriorating affects, is bring-

-ing it forward as a valuable substitute for cedar block in localities where lightness and quiet is desirable in a pavement. The blocks are four inches in depth four inches wide and vary in length from six to twelve inches depending on the size of the timber from which they are cut.

Test pavements in Chicago. Those treated blocks which have been used in Chicago are known as the Kreodone-Creosote or Creosote block deriving their name from the Creosote oil used in treating them. The first sample of this pavement was laid on the Rush Street bridge over the Chicago river, in 1899. In order to put it to a test and secure comparative data, the two roadways of the bridge were paved, one with the treated and the other with the untreated Norway pine blocks. The roadways are each eighteen feet wide and are subject to a very heavy traffic of great volume. According to Mr. F. G. Quilty, Assistant Engineer of the Department of Public Works, the bridge is subject to a heavier traffic than any other bridge in the city. A census of the traffic passing over the two roadways is as follows:-

Heavy trucks, drays, etc	3598
Carriages, buggies etc	2078
Light vehicles	3275
Automobiles	165
Total	9116 vehicles.

It represents a total in a period of seventeen hours from 7 A.M. to 12 o'clock midnight on December 19, 1902. This amount may be taken as the normal, and though not expressed in tons is significant when one considers the nature of the industries in the immediate vicinity of the bridge. To the south are located all the large wholesale grocery, sugar and coffee houses while on the north the area is well filled with factories, warehouses and freight yards, all furnishing an extensive traffic in both directions. In December 1902 the untreated roadway was so far gone as to need replacement. Many of the blocks had worn thru to the sub planking. As the treated block roadway showed no necessity of repair a few of the treated blocks were torn up however, to determine what wear had taken place during the two and one half years that they were down. It was found that there was no sign of natural deterioration apparent and the wear caused by traffic averaged about 1/8 of an inch per year. They were sound, unbroken and except for the wear, were true to their original size. This short piece of pavement is subjected to an extreme condition in point of traffic.

Another piece of creosoted block pavement was laid in Michigan Ave in front of the Auditorium

Hotel in 1902, and though this piece is subject to a large volume of traffic it represents another extreme of traffic conditions in that the vehicles passing over it are of a lighter character and only such as are permitted by the Park Board rules. This piece of pavement was in excellent condition in the Spring of 1905 and gives evidence of being a high class pavement. The portion of Michigan Ave between the Auditorium and Van Buren St. was paved with asphalt block, but these are about to be displaced by creosoted blocks.

Their future With the experience furnished by these two pieces of treated block pavements it would appear that the creosoted pine blocks are well adapted to withstand all forms of traffic. The age of these pavements is too brief to draw any definite conclusions, yet the experiences of Paris which has over 75 miles of such pavements in its heaviest travelled streets, and London which has a mileage greatly exceeding that of Paris and where under traffic much greater than that met with in the United States, these pavements are known to have a life exceeding 18 years, would indicate that this form of pavement will gain in public favor. Where something more durable than can be secured by the use of asphalt under heavy traffic, and something more noiseless than stone in the

business district is desired, treated blocks will find favor. Already public sentiment is averse to the noise of the granite pavements in the downtown retail district, and it is quite probable that the next five years will witness a change in the form of many of the street pavements in that district. Which shall it be? Present construction in State St. points to the former though each year will add to the advocates of the creosote block as the results become better known. Its use is extending in this country.

The latest treated block pavement. During the past year, 1904, a more extensive stretch of creosoted block pavement was laid in Chicago. Taylor St. from Canal St. to Blue Island Ave. was paved with this material. The length of this stretch is 2/3 of a mile. The street is a comparatively narrow one with a double street railway track in it. The old rails which were in the street have been replaced by grooved rails, the foundation under the track was well rammed, and on the whole the condition resulting is such that the blocks will undergo a thorough test unless some unlooked for tearing up becomes necessary before the blocks shall have begun to show marks of deterioration or wear from traffic. In the same street west of Blue Island Ave. a

sheet asphalt pavement has been laid and though not liable to so heavy a traffic as the portion between Canal St. and Blue Island Ave, it will furnish an interesting and valuable comparison as time passes.

CONSTRUCTION OF CREO. BLOCK PAV.

The foundation of the Taylor St. pavement consists of a portland cement concrete 6 inches thick laid on a subgrade which was thoroughly rolled lengthwise of the street by a ten ton roller. It was impossible to roll cross wise of street owing to the presence of the street car tracks though my observations in similar cases has convinced me that the fact that the rear wheels of the roller are not more than 18 inches wide, these find any soft spots which may be caused by longitudinal trenches as well as those running across the street. Upon the concrete base is spread a layer of sand in such quantity as to insure a uniform thickness of one inch when it is compacted. This thickness is secured by the use of a template just previous to laying the block.

After bringing the sand cushion to the necessary thickness, the treated blocks are placed in parallel courses at an angle of 45° to the center line of the street except on alley wings where they are laid

perpendicular to the axis of the alley. All blocks are laid with the fiber of the wood in the direction of the depth of wearing coat of pavement. The specifications require the blocks to be cut from long leaf Southern pine and conform to the following size:- 4 inches deep, 4 inches wide and not less than 5 nor more than 10 inches long. The timber must be sound and all blocks must be square edged, free from bark, shakes loose or rotten knots, red heart or dead timber and other defects which will interfere with the placing of the blocks.

TREATMENT The specifications prescribe the following method of treatment:- "after the blocks have been inspected and found satisfactory they shall be placed in an air tight chamber, where by means of superheated steam and the use of a vacuum pump the sap in the blocks shall be vaporized and the moisture in them removed. When the blocks are thoroughly dry, the wood preserving oil shall be admitted into the cylinders and subjected to a pressure which shall be maintained until twelve pounds of the oil shall have been forced into each cubic foot of timber and until the oil shall have impregnated the timber thru the entire depth of the block and to the satisfaction of the Board of Local Improvements. The wood preserving oil shall be Kreodone- Creosote paving oil or any creosote paving

oil which shall in the opinion of the Board of Local Improvements be equal thereto in quality for the purpose."

Jointing The joints of each course are broken and each course is driven tightly to the preceeding. The gutters are formed by placing four courses of blocks adjacent to the curbs and parallel to the outer line of street. Expansion joints are provided as follows:- "The joints running parallel with and at the gutter shall be one inch in width and at intervals of 100 feet along the roadway the joint running across the same shall be one half inch in width. These expansion joints shall be filled with bituminous cement." After laying the blocks the surface of the roadway is brought to a uniform contour by rolling with a five ton asphalt roller.

Filler. It is specified that "the joints shall be filled with bituminous cement or pitch which will resist the solvent action of the wood preserving oil, and which will not be brittle at 0°F. nor flow at 200°F. The cement shall be applied at a temperature of not less than 300°F. or at a higher temperature if necessary to render it fluid enough to properly run into and fill the joints. The blocks must be thorough-ly dry before the cement is applied. Extra care must be taken and extra material must be used

at the gutters and around catch basins, manholes, etc in filling all joints in both the paving and along the curbing to affectually prevent the leakage of water into the "sub roadway". Immediately after the hot asphaltic cement is poured into the joints and spread over the surface, a layer of sharp torpedo sand is scattered over this so that the finished thickness approximates one fourth of an inch. To provide for the perfect adhesion of the asphaltic cement to the blocks in the joints, it is specified that if from any cause the blocks should become wet before applying the hot asphaltic cement, they shall be taken up and reset, should the engineer so direct. Where the pavement blocks abutt against a curb wall, the joints between them and the wall must be filled with a cement mortar composed of one part portland cement to three parts of clean sharp sand.

MACADAM PAVEMENTS.

Previous to 1849 all improved streets in Chicago were either planked or graded. No form of stone pavement had yet appeared in the streets. Stone block pavements had been proposed but it was thought useless to lay stone in the streets of the city. "It did not seem a profitable investment for the city to lay down a pavement which would sink out of sight in one or two years". The street grades were low as compared with the lake level and afforded no well drained foundation. Public opinion varied, however upon the relative merits of stone and plank. In 1855 a short stretch of macadam pavement was laid in Wells St, now Fifth Ave., from Van Buren St. to Congress St. and its use there marked the beginning of the industry in Chicago, if not the beginning of the introduction of the more substantial forms of pavement in the city. In 1856 Mr. De Golyer invented a pavement and did some work in Lake and South Water Streets, but it was thought that it gave "general dissatisfaction". It was nothing more than a cobble stone pavement laid in a very careless manner. Its use accomplished a purpose however. Discussions arose among the inhabitants of the city regarding pavements in general. Macadam was advocated and oak planking had its warm admirers. In the fall of 1857

the "Macadam system" won at the polls over the "plankers". Coincident with this victory for macadam, came the introduction of Nicholson wood block pavements and macadam took second place in public consideration. In spite of its cost, $2.30 per square yard, Nicholson block seemed better adapted to meet the conditions of traffic then existant.

Early History. At the close of 1875 the mileage of improved streets was as follows:

Macadam	6.16
Cinders	8.44
Graveled	8.51
Nicholson Block	94.04
Total	117.15 miles.

These figures show a very slow growth in the use of macadam. At the close of 1882 with an area of 36 sq. miles within the municipal limits the total street mileage amounted to 651.0 of which 183 miles were improved as follows:-

Macadam	18.57
Wood Block	143.24
Stone Block	2.94
Asphalt Block	1.66
Graveled	7.42
Cindered	9.25
Total	183.08 miles.

That its use was not more extensive can be attributed

to the narrow limits of the city and the fact that the greater percentage of improved streets were confined to the business portion of the city; and the introduction of macadam in such streets did not seem advisable nor economical because of its dustiness in dry weather unless frequently sprinkled. In the spring of the year when the frost was coming out of the ground macadam became muddy and easily broken up by heavy traffic. Then again many of the business streets contained car tracks and their presence precluded anything but a pavement which would present a good joint between the rails and the pavement proper. Macadam was inadaptable for paving between the rails.

Use of macadam extends Its more extensive use may be said to have commenced in 1880 when 2.49 miles of macadam were laid. Table I also its rise in mileage from that date. About that year, or more properly 1879, Mr. Chas. S. Waller, then Commissioner of Public Works, suggested a form of macadam pavement constructed along the following lines:- "Prepare the roadbed so as to be even and compact thoroughly with a fifteen ton roller; let the first covering be rubble stone carefully placed by hand, broadest face down; cover this with twelve inches of macadam, six inches at a time thoroughly rolled to bond it well

then top it with four inches of crushed granite trap rock or some other equally hard stone accessible and not too expensive, that will not disintegrate thru the action of the weather, nor pulverize into dust under the pressure and wear of vehicles upon it; roll this down thoroughly so as to compact and bond it well, and it will give not only a durable, but pleasant street to drive on. The expense will probably not be exceeding fifty percent more than our best wooden block pavements, while there is scarcely any limit to the durability of such a pavement with timely and proper repair".

The above is interesting for the reason that the present practice in general follows the lines suggested. When this construction was advocated the street grades were several feet above those in the fifties. It seems an excessive thickness for a macadam when such is given "proper and timely repair", but the latter condition seldom obtained and the pavement was left to live a natural life and be replaced when traffic had worn it to such an extent as to make it disagreeable to drivers and destructive to vehicles. Where a pavement is left to wear away without occasional maintainance thickness is essential yet even then it does not form an economical construction, for long before such a pavement is worn out, traffic shuns it owing to the ruts which are

almost sure to appear under a constant traffic thru all seasons of the year. The stone used in the macadam pavements then laid was limestone from the local quarries.

At the close of 1888 the pavements of Chicago were distributed as follows:-

Wood Block ------	275.81 miles
Macadam ----	31.80
Medina Stone ----	2.58
Granite Block ---	13.07
Sheet Asphalt ---	3.34
Asphalt Block ---	4.11
Gravel ----	7.44
Cinders ----	9.91
Oak planks ----	0.47
Total	348.53 miles

The unimproved streets amounted to 408.04 miles making the total street mileage 756.57. During the same year work to the extent of $1,540,329\frac{70}{100}$ was done in new pavements divided as follows:-

Cedar block ---	47.15 miles
Macadam ---	3.67
Granite Block ---	3.04
Planking ----	0.47
Total	54.33 miles.

The following year the annexation of Hyde Park, Lake, Lake View, Jefferson and a portion of Cicero increased the street mileage to 2,047.28 miles

which were distributed as follows:-

Unimproved streets		1419.46
Improved streets:-		
Cedar Block	342.59	
Macadam	205.98	
Medina Stone	2.58	
Granite	18.75	
Sheet asphalt	4.14	
Block "	4.11	
Gravel	40.44	
Cinders	9.91	
Planks	0.47	628.97
Total		2047.43

The various towns annexed furnished the following amounts, together with that existing in the city previous to annexation.

	Improved	Unimproved
Chicago	381.89 mi.	374.68 mi.
Hyde Park	114.67	406.83
Lake	37.36	293.20
Lake View	44.23	83.47
Jefferson	—	232.96
Cicero	—	78.39
Totals	578.15 mi.	1469.13 mi.

making a grand total of streets equal to 2047.28 miles. The macadam pavements, as is shown by the figures for both years, increased

from 31.80 miles to 205.98 miles. The gravel increased from 7.44 to 40.44 miles. The total mileage of improved streets annexed amounted to 578.15 minus 381.89 or 196.26 miles. The increase in macadam mileage was 205.98 minus 31.80 or 174.18 miles, and that of gravel was 40.44 minus 7.44 or 33 miles. Adding the increase in macadam and gravel we get 207.18 miles of pavement increased in the form of gravel and macadam. These figures are evidence that the entire mileage added consisted largely of macadam pavements. The city built 38.45 miles of macadam during 1889 but in the light of its use in the city proper previous to these additions, it is safe to assume that they were built in the streets of the annexed towns.

The following year Gano, Washington Heights, West Roseland and part of Calumet were annexed to the city extending the number of miles of streets to 2235.71 miles; though these additions brought no improved streets into the city area but increased the city's area to 181½ square miles.

The above data is given to show the extensive use to which macadam was put as a paving material in the suburban towns about Chicago previous to 1889. A glance at table I will also show that

in subsequent years macadam was laid second in amount to wood block, and has retained that place as a standard form of pavement up to the present time. During the years 1900, 1901 and 1902, it superceeded wood block pavements in the amount laid in those years, but since the latter date sheet asphalt ranks first, with macadam a close second.

Limits of Use The annexations to Chicago brought within its boundaries a large suburban population, and in view of the conditions of traffic met with in those parts of the city macadam formed a pavement cheap in first cost and adaptable to the conditions encountered there. As now laid macadam is confined to the more remote districts of the city which are devoted mainly to dwelling houses, and to the boulevard systems under the control of the park boards. Its inadaptability to business streets and even to thickly populated sections of the city with but moderate traffic, is recognized. It cannot be considered a good city pavement where the traffic is in excess of that encountered on the boulevards. Even where all conditions of traffic are favorable it is necessary to keep the pavement sprinkled in dry weather to make it inoffensive to pleasure drivers and pedestrians on either side of the roadway, and less damaging to abutting tenants. Where the traffic is sufficient

in amount to grind the surface into a dust, such a pavement becomes very disagreeable to both drivers and pedestrians owing to the pasty mud which is formed by sprinkling, or after a rain storm. It is also conceded that a macadam pavement is soon destroyed by traffic if it exists where the surface is moist.

Mistakes in Selection Some mistakes have been made by laying macadam in streets which formed the only avenues for traffic in a rapidly growing subdivision. A number of streets in the south west portion of the city are striking examples of such conditions. It is true that such pavements were laid under circumstances not altogether controllable by city authorities because the law vests so much power in the property owners as regards selection, but their condition after a few years of use emphasized the necessity of a better study of the conditions apt to arise after the improvement of a street is made. Instances are numerous where such pavements are the selection of speculative real estate dealers who look to cheap first cost and, being in possession of the property to such an extent to control such selection, the wishes of those who already own property and reside in the districts are altogether ignored. In selecting a pavement for such districts the interests of those on the ground should be recognized

as they represent a class which must eventually tolerate the ills of a pavement, or enjoy its merits. In the light of the conditions of these streets after the ravages of a traffic consisting of building material wagons, etc; and the absence of any maintainance, it is inadvisable to lay such pavements unless the residing property owners desire them or better yet when the city authorities are possessed of data concerning the conditions arising from the improvement as would warrant the selection of macadam for the street.

Where advisable. In streets subject to traffic above that found on the boulevards of the city macadam has nothing to recommend it beyond the element of first cost. In the outlying districts, such as the suburbs of the city, where travel is infrequent and the street width is such as to permit parking on each side of the roadway, macadam is permissable and advisable if desired by the residents. It is low in first cost and consequently capable of adaptation to conditions where weather rather than traffic will ultimately destroy the pavement. In wide residence streets with a well sodded parking between the curb and walk, and where a little dust and mud is tolerated, macadam forms a good pavement when accompanied by proper and timely maintainance and when kept sprinkled during the hot summer

months. In localities where wood pavements are advisable because of their noiselessness but would fail by rotting long before traffic conditions necessitated replacement, macadam pavements are the proper forms to use when cheap first cost is essential.

Causes of conditions of some macadam pavements.

But the inadequacy of the funds for maintaining and keeping the streets of Chicago clean makes the macadam pavements generally neglected. This condition of affairs is deplorable and unless some change in the law is made whereby a fund can be created for the cleaning and repairing of macadam pavements as well as others, macadam should be abandoned for some other form less objectionable from a sanitary point of view. It cannot be disputed that the objections held out against cedar blocks as regards sanitation are just as potent against macadam if the accumulation of droppings are permitted to remain in the gutters. Such objectionable material left in the streets is soon ground up by traffic into a fine dust which, with the dust of the material forming the pavement, is carried by the winds in dry weather into the open windows of dwellings and into the eyes of pedestrians, and forms a source of disease.

CONSTRUCTION

The older macadam pavements in Chicago were built entirely of limestone. The latest practice in macadam construction consists of laying a foundation of limestone and upon this a layer of crushed granite, binding gravel and granite screenings to form the wearing coat. This practice has produced good results. Though the granite broken stone and screenings used as the dressing coat do not possess the binding qualities common to limestone from the local quarries, its use adds to the life of the pavement, preserves a more uniform surface where a good grade of binder gravel is used, and presents a darker shaded surface which is consequently less injurious to the eyes during bright sunny days.

The method of procedure in building macadam pavements is as follows:- the subgrade is brought to grade by a gang of men working with shovels and giving the surface the necessary fall to inlets. Then the subgrade is thoroughly rolled by a roller weighing from eight to ten tons, working in a longitudinal direction. Any depressions which develop during the rolling are immediately filled with sound material and again rolled. Upon this

rolled bed a layer of broken lime stone varying in size from three to six inches in greatest dimension is spread in such quantities as to make the finished layer an average of six inches thick, the layer being seven inches thick at the crown and five at the curb. To facilitate the spreading of this layer, the material is brought to the street in wagons of known capacity and dumped in piles which will cover a previously calculated area. The amount of subgrade area covered by each wagon load being known, the distribution of the material on the streets is consequently more easily made. The piles left by the wagons are spread into place by means of steel forks, the blades of which are bent at an angle of 90 degrees with the axis of the handle. In the process of spreading two men are employed to manipulate one fork, the one pulling on the handle, the other pushing in the direction of the moving material by means of another fork attached by wires to the blades of the fork working thru the broken stone in the operation of spreading. In this manner the material is rapidly spread.

To guard against the accumulation of material in excess of that necessary to secure the specified thickness at the curb and thus destroy the grade necessary to secure perfect drainage toward the

inlets, the foreman marks the curb wall at intervals along the length indicating the height to which each layer is to be brought at such points. The crown and intermediate points are brought to the top of stakes previously driven to the grade desired at those points.

Upon the layer of coarse limestone forming the first layer, is spread a layer of screenings sufficient in amount to just conceal the stones and fill the interstices after flooding and rolling. In rolling the screenings are sprinkled frequently to keep them quite wet and better enable the individual particles to find their way into the interstices under the weight of the roller. The rolling continues until there is no great rolling of the material before the roller and the surface is fairly uniform.

A layer of medium sized broken limestone is then spread over the surface in such an amount as to make an average thickness of layer equal to four inches, five inches at the crown and three at the curb. The stones of this layer vary in size from one inch to two and one half inches in greatest dimension. Upon this layer is likewise spread a layer of limestone screenings, which are thoroughly worked into the interstices of the last layer by frequent sprinkling before an eight to ten ton roller.

When the surface is thoroughly compacted and brought to a true and uniform surface, it is covered with a coarse crushed granite broken so as to measure not more than two inches and not less than one and one half inches in any dimensions. This granite course is covered with a binding gravel, consisting largely of red clay interspersed with small pebbles of a calcareous structure or formation. The gravel is added in such amounts as to completely fill all the voids in the granite broken stone layer. The latter is then rolled after flooding the surface.

Following the rolling a layer of granite screenings one half inch thick is spread on the surface and rolled into the granite stone layer, and binder gravel. The last layers over the limestone consisting of the granite, binder gravel and screenings average three inches in total thickness, four inches at the crown and two at the gutters.

Crosswalks Crosswalks are provided by laying several courses of vitrified brick block across the roadway at street intersections so that the footway is from five to six feet wide. Where the inlet to the catch basin is located at the street corners a flag stone is set out from the curb a few inches to provide a water course between it and the curb. The crossing walk is then laid between these flag stones.

GRANITE BLOCK PAVEMENTS

With the rapid deterioration of cedar block pavements and the delays and annoyances attending their replacement in the more congested and business districts, a form of pavement with other qualifications than cheap first cost to recommend it was necessary. It seems true of all the larger cities of the country that, after experimenting with wood block or after passing thru those stages in their development calling for a cheap form of pavement, stone in some form was adopted as the standard pavement. Chicago had realized the necessity of something more permanent than wood or macadam in her down town streets about the year 1879. The introduction of stone pavements of the dressed block pattern is said to date from 1849 in this country. In fact the earliest and most common pavements consisted of some form of irregular dressed blocks of stone. Its use in Chicago at present is limited to the more travelled thoroughfares. Although a durable pavement its smootheness after some years of use, is causing it to be abandoned in streets which have a large pedestrian traffic, a large volume of light wagon traffic and where the abutting buildings are of an office or retail business character, employing a large number of people.

since its introduction in Chicago however, most every street in the down town district has been paved with granite block. Those exceptions which now exist are recent improvements which were preceded by granite blocks. The district between the Chicago river on the north and west, Michigan Ave on the east and Twelfth Street on the south is paved almost entirely with granite block. In the outlying districts where cedar blocks have outgrown their usefulness there is a demand for stone block pavements in the more travelled streets, notably Milwaukee Ave, West Lake St and Halsted St.

Granite blocks also form a desirable pavement for short stretches of street adjacent to breweries, lumber-yards, warehouses and factories, but their use in streets of a semi business character does not seem advisable even though they are popular in such districts. This popularity is sometimes the result of discouraging experience with wood block, and before the merits of another form of paving material are fully weighed the cry is for the hardest possible pavement.

History. Stone block pavements were agitated as early as 1876 when J. W. Wilson then Superintendent of Streets and bridges had this to say in

his annual report:- "I am of the opinion that for streets occupied by wholesale firms and manufacturers where traffic is principally by heavily laden teams, pavements of block stone, of uniform thickness, properly laid will eventually meet with the favor of property owners. The objection to stone pavements is the original being greater than wooden block, and the noise made by trucks and wagons, and wear and tear on horses and vehicles. This is offset by the fact that the lasting qualities of the pavement is three to four times that of wooden blocks. For instance La Salle St from Randolph St. to Washington St. was paved with stone blocks from the canal quarries in 1858, nineteen years ago and is still in condition, with ordinary repairs, to last several years".

The total amount of stone pavement in the city at the close of 1876 was but 0.53 mile. Its use however was not readily adopted. In 1879 only 1695 feet of Medina stone was laid, in 1880 but 1035 lineal feet. In 1882 the amount laid reached 1.24 miles, 0.07 mile of which was granite block on macadam foundation and 1.17 miles were Medina stone on sand foundation. In speaking of its utility in the streets of the city Commissioner of Public Works, D. C. Cregier says in his report for 1882:-

"The advocacy of substituting stone for wood in street paving is commending itself to the favorable consideration of the property owners on most of our leading thoroughfares. Indeed the era of stone pavements may be said to have been inaugurated, and even at this date the demand and willingness to pay for this class of improvement on the part of the citizens is far greater than can be met owing to the city's inability to pay for intersections, etc. The comparatively small appropriations that can be made for this part of the work will necessitate delay in the paving of several leading streets during the ensuing year".

In that year the total mileage of improved streets was 183.05 miles. The total area of the city was 36 square miles, and the streets opened to travel amounted to 651 miles. This demand for stone block pavements was confined entirely to the property owners in the down town district. In 1883 two and one half miles of granite and medina stone block were laid. In his report for 1883 Mr. Cregier says:- "The granite block pavement is meeting with general favor by our citizens and bids fair to supercede all other forms of pavement on the streets subject to heavy traffic. Thus far this kind of pavement has been laid with

great care and under constant and rigid super-vision. The specifications require the roadbed to be properly graded to form and puddled with water or rolled and all foreign substances removed, after which a bed of clean broken stone of uniform size is laid from 6 to 8 inches thick; upon this is spread a bed of fine bank gravel which possesses peculiar serviceable qualities, sufficient in quantity to fill the interstices of the foundation stone, and leave at least one inch on the surface; after being flooded with water, the mass is then rolled with a steam roller of 15 tons weight until it becomes solid and unyielding; a bed of fine lake shore sand is then spread over the surface from 1½ to 2 inches deep upon which the granite blocks are laid to grade line. The blocks are 6 to 10 inches long, 3½ to 4½ inches wide and 6 to 7 inches deep so quarried that they have fair faces and that the joints will not exceed from 3/8 to 3/4 inch openings when the stones are in place: all stones not conforming to these dimensions are rejected. When the blocks are thus laid the surface is covered with clean, screened dry roofing gravel filling the joints after which each stone is rammed, causing the filling gravel to sink in the joints from 3/4 to 1 inch below the surface; the spaces

thus formed are carefully filled with hot asphaltic composition, flush with the upper surface. The entire surface is then covered with a coating of fine dry screened gravel when the street is ready for public use. It is believed this character of pavement is far more durable and therefore in the long run cheaper, than any other kind of pavement that can be laid on our business streets; and when the sanitary advantages are considered, stone pavements are vastly superior for such localities to wood or macadam no matter of what kind, how prepared or how well laid the latter may be". The above furnishes a good idea of the practice in the construction of stone block pavements in Chicago in that period. It is interesting too for the reason that it shows the thought given to public improvements by Mr. Cregier. That his advocacy was well taken by those interested in permanent pavements is attested by the extensive use to which that pavement was put in the wholesale and retail business district east of the river.

After discussing the tendencies in other large cities Mr. Cregier further states that, "the only objections to granite block pavements is the noise produced by traffic over it; this is perhaps

a serious matter but a quiet and noiseless pavement possessing lasting and substantial qualities is hardly within the range of probability at present. The line is to be drawn therefore between economy and sanitary conditions on the one hand, and the health, expense and inconvenience of the public on the other. Granite pavement as laid in our city, it is believed obviates all sanitary objections and with joints of the blocks filled with asphaltic composition, the noise is greatly decreased, while its lasting qualities makes it cheaper than wood, therefore meeting the former demands". Even at the present time the noise caused by traffic over granite block pavements is one of the principal objections of that form of pavement. That it is destructive to both horses and vehicles is undeniable; still it remains the one pavement which will withstand all the wear of the most destructive traffic with an economy to the property owner such as cannot be claimed for any other form of paving material.

Effort to secure better blocks

Attempts were made to improve the physical nature of the blocks to reduce the objections caused by the noise. In general however the construction remained the same as was describ-

-ed in Mr. Cregiers report. The macadam was replaced by concrete. In 1900 however, an attempt was made to eliminate some of the annoyances to pedestrians and traffic in general, by specifying a more uniform size of block to insure a joint between the blocks not to exceed 1/4 of an inch in width. This specification could not be met by the contractors then paving with this form of material. The requirements necessitated greater labor in the dressing of the blocks, and from the amounts available it appeared that the quarries were not able to produce them in quantities which would "encourage continued efforts in that direction". To convince himself that the representations of the contractors were not visionary regarding the scarcity of blocks conforming to the specifications, the Commissioner of Public Works, L. E. McGann, advertised for 30,000 sq. yds. of granite blocks and did not receive a single offer

Other objections to stone blocks. Besides the annoyance due to noise there are other features of stone block pavements that must not be overlooked. To those familiar with the granite block pavements in the down town district, it is evident that the expense of cleaning such pavements is no small

item. After a few years of use the granite blocks wear smoothe and take on a rounded shape, which gives them the appearance of cobble-stones in the pavement. The original width of the joint, limited to a maximum of 3/4 of an inch, is soon increased near the surface by the spalling of the corners of the blocks under traffic. The asphaltic filler does not withstand the constant impact of traffic and soon wears away and permits the corners of the blocks to chip more readily. This leaves the surface rounded and deeply grooved. The grooves gather and hold filth and make the proper cleaning of these pavements a difficult proposition. The only affective method of cleaning such pavements is to employ hand labor. Machinary which operates only lengthwise of the street is ineffective and only brushes the top of the blocks, leaving the transverse joints or grooves filled with dirt. Mr. Richard Fox who has been superintending the cleaning of streets in the down town district during 1904 and 1905 for the Merchants Associations has prepared data on cost of cleaning the various forms of pavement in his district. He states that the differance in the cost of cleaning

stone block pavements and asphalt pavements in his district is sufficient to pay the interest on the cost of replacing the former pavement by asphalt. Then again the rounded surface of the blocks, combined with the smoothness of the surface, makes such a pavement annoying to pedestrians as well as preventing a foothold for horses. Cases are numerous when horses were unable to secure a good footing and were thrown to the ground in their effort to pull the load behind them.

CONSTRUCTION

Nature of Blocks. The granite blocks now used in the pavements of that class in Chicago are made from rock belonging either to the syenite or granite group of crystalline rocks. They are known as Georgia or Wisconsin granite depending on the quarries supplying the product. The Wisconsin granite has been used extensively. The blocks must conform to the following specifications:- "the blocks shall measure from 3 to $3\frac{1}{2}$ to 4 inches in width, 8 to 10 inches long, and 5 inches in depth, and must be so dressed as to have substantially rectangular plane surfaces, so that when the blocks are in place the joints at the ends and sides shall average

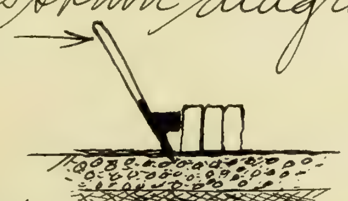
1/4 inch in width. Soft and weather worn stones obtained from the surface of the quarry, and stones which wear to a polish under traffic, shall not be used." In many of the older granite block pavements the latter requirement does not obtain. The blocks are smoothe and polished, affording no foothold beyond that offered by the spalled corners. The greater number of such pavements are made with block which is too hard; the principal constituent of the material being quartz which is hard and brittle, it is readily worn to a smoothe and polished surface under the grind of wheel tires and the impact of shoes. In the past year a light shaded block has been used. It is not so rich in quartz and properly belongs to the syenite group, the characteristic of which is a comparatively small percentage of quartz with a predominance of feldspar. Feldspar is not so hard and brittle as quartz and is not given to wearing to so glossy and smoothe a surface as the quartz in granite. Moreover the presence of a fair percentage of hornblende makes the rock more easily worked. Syenite is more elastic than granite, and while wearing more rapidly than the granite rich in quartz, the wear is more uniform and as a

consequence it is less liable to become rounded after a few years of traffic than granite rich in quartz.

Laying Granite Blocks The blocks are laid in uniform courses across the roadway between the gutters except at intersections where the blocks are laid at an angle of 45 degrees with the center line of the roadway. The space between the blocks when in place should not be less than 1/8 inch and not exceed 3/8 of an inch. Care is taken to make each course of uniform thickness by using the same width of block as near as possible the full length of the course. The longitudinal joints are broken by a lap of not less than 3 inches. The gutters are formed by direction of the engineer, though the common practice is to lay four courses of blocks parallel to the line of the curb and with a slight fall from the curb to the last longitudinal gutter course.

My observations on streets where granite blocks were laid convinced me that it is almost impossible to lay blocks with the minimum joint space of 1/8 of an inch. In the first place the irregularity of the faces prevent this with the ordinary method of handling them by hand; and in the second

-place the extreme weight of the block-prevents its being set in place very closely without virtually throwing the block in place hard against the preceeding course- Where the latter method is used to bring the blocks close together, the possibility of carrying some of the cushion sand into the joint also renders small joints mere chances. It appears to me that some device taking the form of an iron rod resembling a crow bar could be used effectively to bring the successive courses to a closer bearing than is now secured in the laying of stone block pavements. The blocks could be laid as they are now by hand but an additional man should follow up the block setters with the bar and, with a leverage in the foundation, force the blocks against the last laid course. The impliment is shown diagramatically below.



Some such treatment would undoubtedly secure a more rigid pavement and reduce the size of the joints considerably over that now secured in such pavements. The blocks are too heavy for a single man to place with a good bearing one against another.

Filler for joints Immediately after laying the blocks the spaces between them are filled to within two inches of the surface with fine dry gravel, free from loam and dust and small enough to fall to the bottom of the joint with but slight motion of the block by ramming. The blocks are then rammed to a true surface and firm bed with a 75 lb. rammer. No cracked or chipped blocks are permitted to remain in the pavement. After the blocks have been thoroughly rammed into place, the joints are completely filled with a paving pitch which is the direct result of the distillation of "straight run" coal tar and of such quality and consistency as is approved by the Board of Local Improvements. The paving pitch is generally poured into the joints at a temperature of not less than 280° F. by means of a vessel resembling the ordinary sprinkling can without the rose sprayer. It should always be applied hot enough to penetrate to the bottom of the joint without cooling. The total quantity spread should be two gallons per square yard.

Following the spreading of the pitch, and while it is still hot, the blocks are covered with a layer of dry roofing gravel not less than

3/4 of an inch thick. The gravel used for the purpose ranges in size from 1/8 to 1/2 inch in largest dimension and must be dry enough when scattered to prevent too sudden chilling of the pitch. The tarring and top dressing must be completed to within five feet of the face of the blocking. Following the day in which a certain stretch of street has been paved, it is opened to traffic.

ASPHALT PAVEMENTS

Nature of pavement Sheet asphalt pavements were introduced in Chicago in 1882 when 1141 lineal feet were laid in W. Park Ave, from Center St. to Menominee St. Like all asphalt pavements then laid in the United States the name was derived from a material which forms but 10 percent of the mass composing the wearing coat. It is a mixture prepared by man and in that respect is regarded an artificial asphalt since the genuine asphalt pavement as European authorities regard it, is one made from a material found in nature consisting of a mineral aggregate impregnated with sufficient bitumen to bind the individual mineral particles together and form one homogeneous mass, which only requires heating in order to make it workable. It is also distinguished from block asphalt pavements in that it is an artificial mixture of bitumen and sand, whereas the block is one of bitumen, sand and broken stone, and is made to size under pressure.

Early Development Its early introduction in the United States is attributed to Professor E. J. DeSmedt a Belgian chemist who laid the first sheet asphalt pavement in 1870 in front of the city hall in

Newark N.J. Dr Smedt's early pavements furnished some valuable practical experiments in the material but it was not till 1876 that the sheet asphalt paving industry was started. That year three fifths of Pennsylvania Ave in Washington D.C. was paved with the material, the remaining two fifths of the avenue being paved with Neuchatel rock asphalt. Thus we see the first attempt to give this material a comparative practical test. Following its introduction in Washington in 1876 the use of it spread to other cities; Buffalo in 1878; Baltimore in 1880; Boston in 1881; Erie, Youngstown and Omaha in 1882; Philadelphia, St Louis and Louisville in 1883; New Orleans in 1884 and at the close of 1900 the Barber Asphalt Paving Co. is responsible for the statement that "sheet asphalt pavements were laid in upwards of 150 cities in the United States and Canada". Its rapid development in this country is attested by the yardage laid since 1880. "Up to 1880 there was laid but 300,000 square yards; in 1885 there were 1,800,000 sq. yards; in 1890 - 8,100,000 sq. yds; in 1895 - 21,500,000 sq. yds and in 1900 there were 38,000,000 square yards laid in the streets of this country.

Use in Chicago Its development in Chicago may be illustrated by the following figures. At the close

of 1885 there were but 2.44 miles of asphalt pavement in the city; at the close of 1890 5.09 miles; at the close of 1895 - 30.75 miles, at the close of 1900 100.29 miles, and at the close of 1904 there were 220.0 miles representing 15.31% of the total improved streets in the city. During the year 1904 - 42 miles of sheet asphalt pavements were laid representing 52½% of the total laid during that year. In its present state of development it is a popular, high class pavement well adapted to semi-residence and retail business streets because of its cleansing qualities, elasticity and smoothness. It is the most economically cleaned of all pavements in the city.

Experimentation During the experimental period extending from 1876 to 1890 and a little beyond, and which period included the earlier asphalt pavements laid in Chicago, the asphalt pavements were laid with a mineral aggregate "consisting at one time of course sand, at another of a fine sand; sometimes with a great deal of filler, or fine mineral dust and sometimes with little or none; again at times with an excess of asphaltic cement or a small quantity of it; with asphalt at one time of a hard and at another of a soft consistency" In their year book for the year

1904 The Barber Company further adds: "When defects developed in a finished pavement they were attributed according to the impression of the moment, to the fact that the mixture was too coarse or too fine, too hard or too soft, just as it happened to mark up under traffic or crack under assaults of weather". The results of the early pavements gave rise to "an exhaustive study of the asphalt wearing surfaces" by the Barber Asphalt Co under the direction of Mr. Clifford R. Richardson who is now an authority on bitumens. The object of the investigation was to determine certain irregularities in the wearing coat. Samples were taken from the streets in the various cities where the material was used. No discriminations were made. "Brilliant" successes as well as "conspicuous" failures were included in the samples.

Method of Analysis "The character of an asphalt surface mixture is determined by the amount of bitumen it contains, by the consistency of the bitumen and by the coarseness or fineness of the particles of sand or dust incorporated in it" The amount of bitumen contained in the surface mixture is ascertained by applying a suitable solvent, such as carbon bi-sulphide which extracts the bitumen from the mixture. The consistency is ascertained by the

depth to which a weighted needle will penetrate into the surface of the asphaltic cement, at a definite temper-ature in a definite time. The size of the sand and dust particles is found by passing the particles thru sieves of known size of openings. For the latter purpose sieves having ten to two hundred openings per lineal inch are used, the particles passing the finer sieve being practically dust, and act as a filler to give body to the bitumen between the sand grains. By the use of the solvent and sieves, the surface of an old pavement can be taken apart and its character determined as well as if the original constituents were at hand in the proportions in which they were used for the particular street under investigation.

Many of the pavements taken up by the Barber Company were examined in the manner prescribed above. Pavements exposed to all kinds of weather and all degrees of traffic. Old pavements as well as new ones were subjected to a test. The result of these investigations lead to the following conclusions:- the surfaces having the most bitumen and dust were the most lasting and those surfaces containing the finest sand gave as good results. Those pavements which proved defective and had a shorter life were found to have a small percentage

of bitumen soluable in carbon bisulphide and contained too small an amount of fine sand and dust.

The pavements laid in Chicago from 1882 to 1891 were but experimental in extent. The pavement could hardly be considered a standard at that time. The industry was young and undergoing various changes to correct some of the errors of the previous pavements. The nature of the asphalt itself made its introduction in the wearing coat under various conditions of atmosphere and traffic a matter of experiment. And it was not till suffic-ient time had elapsed to secure comparative data that a more systematic study of the material became possible. The tests of Mr. Richardson for the Barber Co. proved conclusively that the fact that so large a percentage of the wearing coat consisted of sand of varying mesh composition, necessitated a consider-ation of this element of the mixture an important matter in the study of the material. Moreover Mr. A. W. Dow, another authority on the subject, tells us that although the use of different sands will change the physical properties of a pavement somewhat "yet they are principally dependant on the physical properties of the asphalt with which it is constructed".

We thus see that the asphalt pavements were variable quantities and the only reliable test of the material was its action in the street pavement.

Conditions affecting use in Chicago. The uncertainty in the degree of utility derived from such a pavement made its introduction in Chicago slow. The territorial growth of the city and the necessity of some form of pavement for the immediate care of traffic, acted toward adopting the cheaper forms of pavements, cedar block and macadam. For, from an area of 43.8 sq. miles at the close of 1889 and with the subsequent additions made in 1890, 1891, 1893 and 1895 the total area was 187.13 square miles, an area not equalled by any city in this country. It is not surprising therefore, that so little attention was given to the asphalt or any other form of pavement which was then undergoing such extensive experimentation. Moreover a comparison of the costs of the various forms of pavements at the close of 1893, will no doubt emphasize the justice of this ignorance under such circumstances. Cedar block averaged \$1.12 per sq. yd; Macadam 90 cents; asphalt \$2.80 and granite block \$3.00 per square yard. But the excessive cost of asphalt in that and previous years was attributed to the fact that the ordinances made it

essential that the asphalt used be from one source. In 1894 the mayor effected a change in the method of drawing up ordinances so that the material was not limited to one source of supply and the price fell to 1^{61} per yard, and averaged 1^{82} for the year. The drop in price was not lasting however, for in the year 1895 it advanced to 2^{35} as compared to cedar block on macadam foundation at 1^{15} and 90¢ for cedar blocks on plank foundation, while macadam averages 80¢ with a twelve inch course and 60¢ with a nine inch course.

Then again the experience with the meagre mileage of asphalt pavements in the city was such as to discourage its further use. The city was not ready to enter into expensive experiments to learn the mysteries of the asphalt pavements as then laid. In 1884 Dearborn Ave from Chicago Ave. to North Ave. was paved with sheet asphalt under a five year gaurantee which expired in 1889. Commissioner McGann says:- "During this period the contractors had from time to time made repairs as needed, but at the expiration of the gauranteed term a question was raised by the Department as to the unevenness in parts of the street and incipient holes or what would apparently soon be holes, in other parts. The contractors

urged that while some parts of the surface were not so good as the rest, yet as a whole, considering the extraordinary large amount of traffic on the street, it was in a reasonable good condition. Fearing that the cost of repairs would be excessive this Department still declined to refund the retainer, whereupon the paving company submitted the following proposition and it was accepted." Here followed a letter from the contractors agreeing to relay the surface immediately on condition that the gas mains were relaid also and the retainer paid, the company being relieved of all liability under the contract of 1884 upon the acceptance of the relaid surface. In removing the old wearing coat it was found that the natural cement concrete foundation was in a good condition. All defects in the pavement were due to the wearing coat entirely.

<u>Choice of asphalt and foundation</u> Early in 1892 the department of public works "conducted an investigation of the greatest importance touching the quality of asphalt which should be used for street paving purposes". Following the conclusions of New York, Washington, Buffalo, Utica, St Louis, Indianapolis, Baltimore, Rochester and other cities, it was decided that Trinidad Lake asphalt was the best for the conditions met with in

Chicago. It was also recommended that natural cement be abandoned in foundation work and portland cement substituted for it. In speaking of this conclusion J. F. Aldrich then Commissioner of Public Works says:- "It is our opinion that all pavements should be laid upon a concrete base. Such construction insures reliable and homogeneous foundation on which to construct the wearing surface. The great variety of densities encountered in our subgrade demands something more substantial than plank or uncemented stones. Fair results are obtained by domestic cements in the making of such foundations but there can be no doubt that the use of Portland cement would vastly improve such construction. The substitution of portland cement would considerably increase the cost of the work, but the better results obtained would undoubtedly warrant it".

Use of asphalt pavements extends In 1894 Commissioner John McCarthy reports the results of "an exhaustive investigation made of the merits of different kinds of pavements and their adaptation to the character of traffic upon the various classes of streets". He grouped his streets under the following heads:- Purely Business, Medium Business and Residence Streets. In speaking of asphalt he says:-

"The use of asphalt in residence streets is approved by experience and within a recent period a large reduction has been made in the cost of this form of pavement. The bids on asphalt pavements on concrete foundation are lower today than any heretofore received, and as far as I can ascertain the rates are less than offered in any other city in the country. This good result is largely owing to the firm stand taken by the mayor in requiring that all ordinances for asphalt pavement be so drawn that the material shall not be limited to one source of supply. From this and other causes the old figure of $3.00 per square yard has been cut down to $1.60 which is the rate submitted in the latest bid".
As pointed out before this low price was only temporary; the next year it advanced to $2.35. yet it was gaining in public favor in spite of the cost. During the past four years more than 120 miles of sheet asphalt pavements were laid which represented 43 percent of the total mileage of pavement laid in the same period. The price per square yard during 1904 varied from $2.50 to $2.60 per square yard.

ESSENTIALS OF ASPHALT PAVEMENTS

In a paper before the American Society For Testing Materials, Mr. A. W. Dow in 1903 laid down the following six properties which an asphalt pavement must have.

First. "It must be composed of such material that it will not crush or be ground away by traffic at any climatic temperature. To accomplish this the asphaltic cement which surrounds the sand grains must be pliable and elastic at all temperatures for, if it were solid and rigid the mixture would soon grind away".

Second "As an asphalt pavement is laid in one continuous sheet, it is necessary that the cement used be so ductile, even at the lowest temperature obtained, that the pavement may contract without cracking".

Third. "It is also necessary that the pavement be so firm and hard at the maximum climatic temperature obtained, as to withstand the passage of traffic without either being cut into so badly as to be objectionable, or shoved to the side of the street."

Fourth "The paving mixture must be as

dense as is possible, so as to preclude the entrance of water into its voids, for if water enters and freezes the mixture is expanded and becomes spongy for, with a pavement in such a condition, especially if the asphaltic cement is not very pliable, it will wear away by abrasion".

Fifth "The pavement must not contain any material that is acted on by water, for even though it were possible to construct a paving mixture so dense as to preclude the entrance of water into it, yet the mixture being pliable under the passage of traffic, water will work into it if it contains any material that is readily attacked."

Sixth. "The pavement must not contain an asphaltic cement that will age so rapidly as to cause the pavement to lose its pliability before a reasonable period of time".

"A pavement possessing all these qualities will be durable under all normal conditions".

METHODS OF FAILURE

Asphalt pavements, that is the wearing coat, are known to fail in various ways. They may fail or disintegrate by cracking in long cracks that extend with age giving the roadway a checkered appearance. When failure occurs in that form

the pavement is divided into blocks varying in size from one square foot or less to a yard or more square, the size depending largely on the age of the wearing coat. They may also fail by rolling or shoving in a direction parallel to the direction of traffic, giving the surface a wavy appearance. Rolling is not only confined to a direction parallel to the curb but the crowding may be toward the gutter. Then again asphalt fails by disintegration in patches where the pavement wears into a hole which in time extends in size and penetrates to the foundation. All three failures are common to the older asphalt pavements in Chicago. Perhaps none is more apparent to the casual observer than the first method, by cracking. The early asphalt pavements were laid on boulevards subject to the lightest traffic and consequently furnished the very condition which is so favorable to failure by cracking.

Cracking. The light traffic on many of the older asphalt pavements coupled with the fact that it is not very constant in volume affords a condition which makes it difficult to guard against cracking. Failure by cracking is the most conspicuous though failure by disintegration in spots is not uncommon. Such roadways as Ashland Avenue south of Madi-

-son Street, West Twelfth Street west of Ashland Ave and Ogden Ave from Twelfth St. to California Ave. are especially striking examples of failures by cracking. The same is true of a number of streets in the district south of Madison Street and west of Garfield Park where but little traffic prevails even though not limited by park regulations. The pavements bear out the statements of such authorities as A. W. Dow and Clifford Richardson, that such failures are not so common in well travelled thoroughfares owing to the compressive action of traffic. The Ashland Boulevard pavement above mentioned was laid on what was originally a macadam pavement, in the year 1888. That on West Twelfth and Ogden Ave was laid in the following three years. At the present writing these pavements present a surface which is granular and earthy in appearance, an appearance which shows the discoloration of the asphaltic cement by age and the hardening effect by the same agent. This loss of color and hardening of the asphaltic cement results in the loss of the plastic properties of the wearing surface, destroying the cementing properties of the asphaltic cement and rendering the surface more susceptible to the abrasive action of traffic and less able to withstand sudden changes

in temperature. This loss of pliability results in the formation of cracks under traffic and atmospheric conditions. In contrast to a newly laid asphalt pavement these older pavements appear dull and sandy in color, and are more easily scratched with a knife blade and chip when suddenly hit with a sharp tool.

All bitumens used in paving undergo a slow hardening with age and as the cement ages it loses its ductility until at a certain stage the appearance of cracks is unavoidable unless this stage in the life of the wearing coat is prolonged by excessive traffic which makes renewal necessary before such cracks develop. Under such circumstances a pavement rich in bitumen when first laid, and in every way constructed to withstand the contraction caused by temperature changes, while showing no cracks in the first few years of its life even under the most adverse conditions of traffic, will eventually lose its ductility and become subject to cracking. An extensive traffic can do much toward retarding the cracking by counteracting the influence of the sun and moisture, but the conditions of traffic found in the above named streets are not such as would aid materially in preventing cracking. The

Ashland Boulevard roadway runs north and south. The action of the sun on this pavement is as bad as is met with anywhere in the city with the possible exception of those pavements west of Garfield Park. The buildings facing the street are set back from the property line, and the parking is wide. The trees are young and do not offer much shade to the pavement. With these conditions the pavement is subject to the rays of the sun almost the entire day, and with a small volume of traffic, this action has the effect of softening the wearing coat, increasing it in volume and giving it a more porous structure. The action of the sun is cumulative in the absence of traffic, each day adds to the depth of porosity increase, though the infinitesimal in amount. This porosity hastens the loss of pliability in the wearing coat, reduces it to a hard brittle substance less resisting in nature than the sand particles which the asphalt cement binds together.

Sand content The appearance of some of the older asphalt pavements, such as those named above and those in Lawndale Ave. and St. Louis Ave. south of W. Twelfth St. seems to indicate that the sand was not well graded and that it contained an excess of coarse material, or an amount not consistent with present day practice in the industry

on streets where results have been more favorable. At the time these pavements were laid not much attention was given to the sand content of the wearing coat. The sand used was one which was most available at the point where paving was to be done. Moreover, opinions then varied as to whether a coarse or fine sand should be used and one was used as frequently as the other. Experience has shown that a fine sand is the more desirable and where there is a lack of dust in the sand available this is furnished by adding to the sand a powdered limestone or cement. A wearing coat with a well graded sand will hold more asphaltic cement and makes a more compact and resilient pavement, and better resists the influence of the weather. The fact that the sand used in these earlier pavements was coarse, the asphaltic cement content was not sufficient to prevent cracking caused by contraction due to freezing or sudden changes in temperature.

<u>A.W. DOW'S Mixtures</u> In a letter received from Mr. A. W. Dow some time ago, he states:- "While I speak of this defect (cracking) in some of my papers, I want to impress upon you that whether a pavement cracks or not depends entirely on the ductility of the asphalt. There should be sufficient ductility in the asphalt to allow it to contract without cracking when subjected to atmospheric changes from hot to cold. Because a pavement does not crack in the first few winters of its existence it does not of necessity follow that it will not crack later in its life, and in fact

it is hardly possible for an asphalt pavement to last any length of time, no matter how perfectly it is laid, without cracking. This is due to the fact that all bitumens used in paving undergo slow hardening with age. As this hardening proceeds the ductility diminishes until at a certain stage the pavement will begin to crack. The cracking of pavements do not occur from frost as does the cracking of concrete". The ideal paving mixture to reduce this failure to a minimum appears to be one rich in asphaltic cement, the latter being soft enough to work well into the interstices of the sand under traffic and not render the surface liable to mark under traffic. This brings up the question, what mixture is ideal for the extremes of traffic encountered on the streets of Chicago? A mixture which is ideal for one street may prove a failure on another. Mr. Dow states the following general rule in this matter: "On a heavy trafficed street the mixture should contain very little coarse mineral matter, that is, practically nothing retained on the 20 mesh sieve and 30% or more passing the 80 mesh sieve. The asphalt cement should be hard, say 30 to 35 penetration, District of Columbia Standard. The pavement for heavy traffic is made hard because it is not expected that it will last much over six or seven years, as it will be ground away by the

traffic. For this reason you do not have to look to the long life of the asphalt cement. In the case of a light traffic street where the pavement should last over twelve years a much softer asphalt cement, say 60 penetration should be used and a sand graded from coarse to fine, that is, about 20% or more on the 20 mesh sieve and about 20% passing the 80 mesh. As this pavement is liable to last over twelve years it is necessary to make the cement soft to guard against the ageing of which I have spoken. Now you should make your mixtures between these two extremes depending on the location of the street, the climate and the amount of traffic."

Mr. Clifford Richardson in a letter says:- "The older asphalt pavements in Chicago were not made with a well graded sand, carried insufficient filler and much to hard asphaltic cement. Today it is readily understood why these surfaces should have cracked. The more recent work on West Madison St. would be entirely satisfactory were the base under the pavement of a better character and were the surface kept clean."

Tests by Mr. Richardson In a bulletin issued at Long Island City. N.Y. March 10, 1896 Mr. C. Richardson, then Superintendant of tests for the Barber Asphalt Co. announces the results of analyses made on various wearing coats

which represented marked successes and failures. The results show that those surfaces which best withstood the effects of both weather and traffic consisted of a well graded sand with a high percentage of both bitumen and dust. An analysis made of samples from several pavements laid in Kansas City from 1888 to 1895, and each years work representing a different mesh composition of sand shows the following characteristics: that pavement which was considered the best mixture because it presented the best appearance, showed the following composition:

Passing Sieve Number	Percent
200	9.60
100	25.45
80	23.05
50	20.05
40	4.55
30	4.05
20	2.80
10	2.10
Bitumen	10.35

That pavement which calked worst of all and became mushy showed the following composition

Passing Sieve Number	Percent
200	9.00
100	6.30
80	5.40
50	36.30
40	10.80
30	8.20
20	6.50
10	7.65
Bitumen	9.85

The bitumen was "considered low "when compared with the amount found necessary for good surfaces in most cities, but here it is due to the small voids in the sand mixture which will not carry more, and is therefore not as serious a defect as it would be in some other places". The results of these analyses in Kansas City were very encouraging to the conclusions reached as to the composition of the wearing coat.

Practical application of these conclusions in Chicago.

In 1895 the laying of the West Madison St. pavement in Chicago gave the first opportunity to apply the ideas, as to the necessary mesh composition, to practice on a street having a large traffic. The mixture laid in that street was made with three sands, one coarse one fairly graded and one very fine. The latter was used as a tempering sand to make up the necessary 80 and 100 mesh stuff. The sand used for tempering sifted as follows:

Passing	200	mesh sieve	1.5 percent
"	100	" "	40.0 "
"	80	" "	38.0 "
"	50	" "	15.5 "
Retained on	50	" "	5.0 "

"It was a clean, sharp sand exactly suited to the purpose, and when used with the other sand in the proportion of one part to five, gave a mixture which had the following average:

Composition:-

Passing 200 mesh sieve			6.80%		66.6%
"	100 "	"	11.90%		
"	80 "	"	14.60%		
"	50 "	"	33.30%		
"	40 "	"	7.50%		23.3%
"	30 "	"	5.60%		
"	20 "	"	4.50%		
"	10 "	"	5.70%		
Bitumen			10.30%		

"This mixture was only defective in fine dust, 200 mesh, owing to the poor quality of the available stock of dust, and perhaps could have carried a little more 40 mesh material but as a whole good results were expected from it on a street which has car tracks, a heavy traffic and is far from clean".

The pavement above referred to in Madison Street was laid in 1895 from Jefferson St. to Centre Ave. It is subject to a very heavy and variable traffic and has given satisfaction. East of Jefferson St the traffic in Madison St. amounts to 125 tons per foot width of roadway per day of 12 hours according to the report of Mr J. W. Alvord. This stretch of pavement is conclusive evidence that a graded sand is quite essential to a paving mixture to prevent cracking. The traffic in the street is also ample in amount to keep the wearing coat compressed when the temperature is warm

enough to soften it. The foundation in Madison St. is a very substantial one compared to that found in other pavements, notably Lawndale Ave. north of Ogden Ave. The writer had occasion to see a portion of this pavement torn up during the summer of 1904. The concrete was very hard and compact and showed very little moisture. It was broken with difficulty with ordinary picks. Few cracks are apparent beyond those which have developed in that portion of the pavement adjacent to the curb and street car tracks. These cracks are due, for the most part, to a lack of support under the wearing coat and are caused by the heavy traffic rolling over these poorly supported portions and breaking them under the beam action set up.

STANDARDS SOUGHT The results of the investigations carried on by Mr. C. Richardson led to the suggestion of an ideal mixture toward which to work in all paving mixtures. The ideal as used by the Barber Asphalt Co is as follows:-

	Heavy Traffic	Light Traffic
Passing 200 mesh sieve	13 %	10 %
" 100 " "	13 %	} 18 " (100 and 80)
" 80 " "	13 %	
" 50 " "	24	24 "
" 40 " "	11	11 "
" 30 " "	8	} 24 " (30, 20 and 10)
" 20 " "	5	
" 10 " "	3	
Bitumen	10.5	10 "

An analysis of the wearing coats laid by five contractors doing asphalt paving in Chicago during 1904 show the following composition, the analyses being made under Mr. C. Richardson's direction.

Passing Sieve Number	1 BARBER ASP. PAV. CO.	2 CONWAY BROS.	3 STANDARD ASP. PAV. CO.	4 FEDERAL PAV. CO.	5 JOSEPH HANREDDY.
200	11.5 %	5.4 %	10.2 %	16.2 %	6.7 %
100	16.0	30.0	5.0	16.0	4.0 "
80	17.0	18.0	12.0	30.0	6.0 "
50	34.0	31.0	47.0	22.0	45.0 "
40	5.0	2.0	7.0	2.0	15.0 "
30	2.0	1.0	4.0	1.0	9.0 "
20	2.0	1.0	2.0	1.0	1.0 "
10	2.0	1.0	2.0	2.0	2.0 "
Bitumen	10.5	10.6	10.8	8.8	11.3 "

Samples of both the sand and limestone dust used in the pavements laid in Chicago by the Barber Asphalt Paving Company during the summer of 1904, were secured by the writer at their plant and each showed a mesh composition as is shown in the following tables.

MESH COMPOSITION OF MINERAL INGREDIENTS USED IN WEARING COAT			
SAND		LIMESTONE DUST	
Passing sieve no. 200	1.2 %	Passing sieve no. 200	72.2 %
" " " 100	17.8 "	" " " 100	16.4 "
" " " 74	39.7	" " " 74	8.4 "
" " " 50	33.3 "	" " " 50	3.0 "
" " " 30	2.20	ON 50	0.0
" " " 20	2.1 "		
ON 20	3.7 "		

Failure by rolling

Failure of the wearing surface of an asphalt pavement by rolling is due to either one of two things, too soft a wearing coat, or a defective bond between the binder and foundation or between the wearing coat and binder course. It is therefore a failure not due entirely to the materials used but rather a fault in construction or manipulation. Where it exists the pavement is wavy in appearance, showing a tendency to crowd in either a direction parallel to the trend of traffic, or toward the gutters.

Where the failure is attributed to a soft wear-

-ing coat, it indicates a lack of proper manipula-tion of the materials entering in the wearing coat. In mixing the materials the aim should be to secure a well graded sand with just enough asphaltic cement added to fill the voids and make an effective bond between the individual sand particles. Not infrequently during the summer months an asphalt pavement softens under the heat of the sun. If this softening is followed by a heavy traffic it is quite apparent why rolling should occur. The excess of bitumen, instead of acting only as a binder, furnishes a lubricant for the particles of sand to move one on another under the pressure of heavy wagons. It is a defect hard to prevent or guard against on a street with an excess of traffic. Where a heavy traffic occurs one of two ways is open to the contractor in constructing a pavement for such a condition. He may lay a wearing surface with just enough binding material to hold the particles together and thus prevent rolling but still permit-ing a more rapid wearing away of the surface because of the hardness of the wearing coat; or he may use a wearing surface rich in bitumen and depend on a very open, binding coat surface or foundation surface to prevent rolling. The

latter method does not altogether prevent rolling under heavy traffic but the chances of it occuring are fewer when conditions of temperature are favorable. Unless the binder and surface coats are made hard they will slide on a concrete base that is left too smooth. The aim in asphalt construction should be to secure as rough a concrete foundation surface as is consistant with good work. The writer on several occasions during the summer of 1904, saw the concrete laying gang followed by another gang of say two men spreading dry mortar on the surface of the freshly laid concrete and sweeping it over the surface to fill the voids left after tamping was complete. It appears to the writer that much of the rolling of pavements could be prevented by requiring the concrete foundation to be left as rough as is usually obtained by tamping. Under such a condition the surface upon which the binder course is placed, is more open and forms a better bond between the two.

It often occurs that the binder course is made too rich of bitumen. When an excess of asphalt is used in the binder course it is not unreasonable to suppose that some of it will be absorbed by the wearing coat. The fact that the binder

course is made of broken stone and asphalt to act as a binder, suggests that the surface is open and forms numerous voids into which the wearing coat is squeezed under traffic or even during the process of construction under the roller. In this manner the excess of asphaltic cement in the binder finds its way into the wearing coat; and a surface laid to meet the conditions of traffic will fail by rolling when the amount absorbed is such as to render the wearing coat soft during warm weather.

Disintegration in Spots.

Several causes contribute to the failure of an asphalt pavement in spots. When the wearing coat is made so hard as to be brittle in cold weather, the pavement will grind away under traffic in some spots more than in others. When the binder course is being carted to the street the jolting of the material in the wagon separates the stone from the asphalt. The latter sinks toward the bottom of the load. When the binder is unloaded in the street this separation during the haul causes the binder course to be rich in bitumen in some places and poor in others. When rolled in place the binder

course is compact in some spots and open in others. In this manner a wearing surface which is otherwise hard over the entire surface of the pavement develops soft spots over those places in the binder course which are rich in asphaltic cement. Thus a hard wearing coat instead of wearing off uniformly and leave an even surface, disintegrates in spots; the portion above the soft patches in the binder absorbs some of the asphalt making it softer and consequently less susceptible to wear by traffic. The harder portions wear away leaving a number of weak spots in the form of depressions which increase in size and crack in cold weather.

It is not unusual that the wearing coat absorbs enough of the fluxing oil of the asphaltic cement in the binder to make it soft enough to roll and crowd under traffic in such spots. This rolling and crowding in spots leaves depressions in the surface which are rapidly increased in area under traffic. The lack of uniformity in surface thus cause augments the affect of wear by traffic due to the impact of the wheels.

Illuminating gas escaping from mains thru the foundations, is a cause of failure in some paving surfaces. Where the failure is due

to such a cause, the first signs are slight depressions over the affected spots in the street. In time these depressions are followed by fine cracks which increase with age and give the surface a checkered appearance resembling alligator skin. When gas is the cause it can be detected by heating a piece of the wearing coat. The odor of illuminating gas will be present.

Water is the cause of many asphalt wearing coats failures especially at the gutters. Poorly cleaned gutters show this defect when the accumulation of dirt is removed. Where large cracks have appeared in the surface, the asphalt shows a tendency to crumble and grind away more rapidly than other portions of the pavement. The lodgement of droppings and dirt in such cracks help to retain the moisture from the surface and this acts on the asphalt destroying its binding properties.

With a macadam foundation the under side of the wearing coat is more or less affected by water oozing up thru the foundation. Where parking exists on each side of the roadway, failure by water oozing up thru the foundation is most likely to occur. If the surface coat is soft the first evidence of failure is a crowd-

-ing of the pavement in warm weather. This can be attributed to the lack of bond between the wearing coat and foundation due to the lubricating action of the water and the accompanying rot which takes place under the influence of the water on the under side of the wearing coat. When the pavement is hard the affect of water is more apparent in cold weather. The rotting on the under side of the wearing coat becomes so extensive as to furnish insufficient support for the upper portion and in the hardened state caused by cold weather, the surface cracks and crumbles under traffic. In very cold weather the water oozing up thru the foundation may be sufficient in amount to freeze between the foundation and wearing coat and cause cracking.

VITRIFIED BRICK PAVEMENTS

At the close of the year 1904 the distribution of the kinds of pavements in Chicago was as follows:-

ORDER	KIND	MILES	% Total.
1	Cedar Block	625.42	43.50
2	Macadam	457.63	31.83
3	Sheet asphalt	220.08	15.31
4	Vitrified Brick	80.78	5.61
5	Granite Block	43.25	3.01
6	Slag	3.80	0.26
7	Block asphalt	2.28	0.16
8	Novaculite	2.01	0.14
9	Medina stone	1.45	0.10
10	Creosoted block	0.60	0.04
11	Rock asphalt.	0.57	0.04

As is indicated by the above table brick pavements form a comparatively small part of the improved streets in the city. Brick was first used as a paving material in 1890 when 0.38 mile of that pavement was laid in Lake Ave. between Fifty First St. and Fifty Seventh St. Table I shows the amounts

laid since that date and also conveys an idea of the slowness with which it was adopted. For the first five years of its use in the city only 1.31 miles were laid. For the most part these pavements were laid in streets of a very moderate traffic, such as closely approximate the conditions met with in the smaller cities of the country and where brick seemed to give the satisfaction expected from a pavement.

In 1894 Commissioner of Public Works, Jno. M. McCarthy in speaking of an investigation made "of the merits of the different kinds of pavements and their adaptation to the character of traffic upon the various classes of streets," has this to say for brick in what he classed as "Medium Business Streets":- "On the medium business streets of which fair examples are found in Milwaukee Ave, W. Madison St, Ogden Ave and Archer Ave, - the material used should be granite blocks or vitrified bricks. As to the latter it may be said that its use in Chicago will be an innovation but the material has been thoroughly tested in many of the smaller cities of the country and seems to have admirably answered the purpose to which it was devoted. Actual experience in our streets, however, seems to me, will be the only criterion for us because of the difference in the conditions pertaining to traffic as between the smaller cities and Chicago. Our

loads are much heavier than in other cities; and our grades being so nearly in one plane, teamsters gauge their loads by what their vehicles will carry. The traffic in our residence streets equals that in the busiest streets of a smaller city"

It is evident from the above that the experience in brick pavements during the four years previous to Mr McCarthy's report, was too brief to pass upon the relative merits of brick as a paving material in Chicago. Had brick been laid either in Milwaukee Ave or W. Madison St. in 1890 it is quite probable that the experience would relegate that material to the less travelled streets.

In 1895 there were laid 2.86 miles of brick pavement, more than double the amount laid since 1890. For the first time since its introduction brick was laid in a well travelled street in the down town district. La Salle St. from Randolph to Madison St. was paved with brick; and that was the earliest attempt to put brick to a thorough practical test. With its use in the more congested portions of the city it gained in popularity increasing in the amounts laid till 1900. That year 17.64 miles were laid in the city, an amount representing 24.68 percent of the total laid that year and marked the height of popularity of brick pavements. From 1900

to the present it has declined in popularity owing to the poor results it has given on streets of a moderately heavy traffic such as is experienced in La Salle St., Carpenter and Peoria Streets south of the Chicago and Northwestern Railway tracks, Halsted St. south of Van Buren St., Clybourn Ave from Halsted St. to Division St; and numerous others.

In 1900 L. E. McGann then Commissioner of Public Works says in his report for that year:- "The introduction of brick for paving purposes has not been a success in this city. The ordinances prescribing the quality and size of bricks to be used for paving and establishing the test to which they were to be subjected before acceptance, has been complied with but the result has not been satisfactory. On many streets where the bricks have been placed they crumble under the heavy street traffic to which they are subjected, and it is clearly evident that the use of brick in the streets extensively travelled will not be satisfactory either to the property owner nor to the general public".

In his report to the city council for the year 1902 Mayor C. H. Harrison laments the difficulties encountered by the administration in attempting to pave streets against the wishes and inclination of property owners: much criticism is not infrequently aimed at the

administration for the deplorable condition of the streets. Some of it is justifiable yet if more attention were given to the question of selection on the part of the property owners or the interests involved, much better results would be accomplished and the responsibility of failure more justly rested on the shoulders of the administration. The law vests in the property owners the right of selection by petition and this condition results in the choice of a pavement cheap in first cost, regardless of economy. Cheap first cost is the principal argument of property owners in general in their choice of a pavement for a particular condition of traffic. By the continued efforts of the administration and other public spirited citizens who, in the form of local improvement clubs, are giving the question of pavements more than a passing thought, cedar block pavements have been discarded. The public is now convinced that "cedar block pavement will not serve either as an economical nor an effective pavement" for Chicago with "its damp soil and heavy traffic".

With the abandonment of wood block, brick was insisted upon where a hard surfaced pavement was demanded, because of its cheap first cost. This demand resulted in its use even on streets where the traffic was heaviest. "As a result there are

today many cases where brick pavements have been laid in thoroughfares unadapted to their use, with the natural consequence that the traffic in this city of narrow tires and heavy loads has already crushed the paving material to dust".

<u>Where advisable</u> It is now conceded by the authorities in Chicago that the use of brick in the medium business streets is ill advised. Brick pavements are not adapted to the heaviest travel, and are not as noiseless a pavement as wood, asphalt and macadam. There are many examples of brick pavements in Chicago which fulfill every condition required of a good pavement with the possible exception of noiselessness. The pavements in Halsted Street north of Fullerton Ave, in Sixty Third St. from Madison Ave to Cottage Grove Ave and others in the outskirts of the city are examples. In such localities the use of brick should be extended. There are numerous streets in the outskirts of the city where brick should be used in preference to macadam even in the light of the cheapness of the latter, for the reason that brick forms a cleaner pavement than macadam in all seasons of the year and would better withstand the wear with the degree of maintainance now given to many of these streets. In such districts but one objection will hold,

and that is noisiness; yet the small volume of traffic on such streets during the day precludes any annoyance from noise to abutting tenants during the hours of the night. Many of the streets west of Kedzie Ave, south of 39th Street and north of Chicago Ave, might well be paved with brick without experiencing the discouraging results of brick in the more congested portions of the city within the above named boundaries.

Source of present prejudice. Much of the prejudice against brick pavements arose from the poor results of those pavements laid in such streets as Halsted St. from the South branch of the river to Van Buren St., La Salle St. between Randolph and Madison Streets. Harrison St. from Halsted to Center Ave., Peoria St from Madison St to Fulton St., Ogden Ave from Washington St. to W. Twelfth St. and a few others in the above named district.

Halsted Street from the river north to N. 17th St. is exposed to a very heavy traffic. The roadway is about 38 feet wide and has two tracks. The rails are the common girder type of steel rail and as a consequence many of the vehicles ride thru the street with one wheel in the rail tread, the other on the pavement. Such a practice soon wears the pavement into a rut at a point gage distance from the outer rail. The bricks just next to the rails are also spalled and crumbled

by the passage of vehicles from the pavement to the tracks. The bricks just next to the iron manhole covers are also points of weakness. The presence of such fixtures in a street prevents an even settlement of the pavement over the entire surface under traffic and as a consequence the pavement just next to the covers settles more than the covers and this difference in elevation results in the crumbling or grinding of the brick by the impact of vehicles passing from cover to pavement. Aside from the wear caused by the impact of the wagon wheels, the spalling off of corners by the hammering of the hoofs of draught horses soon leaves the pavement in an uneven condition resembling a well worn granite block with the one advantage of not being so slippery owing to the comparative softness of the brick and its width, making the joints closer and affording better foothold.

Peoria St. from Madison St. to Fulton St. has no rails located in the streets and consequently the wear is more evenly distributed. The traffic on this stretch of pavement though not of great volume is very heavy owing to the market facilities in Fulton Street and the team tracks of the Chicago and North western Railway in the immediate vicinity of the pavement. For a distance of two or three feet from

each curb the blocks show no wear whatever, but that portion between these limits is well worn by traffic. Though this pavement was laid in 1900 the wear has been more than that in older brick pavements and illustrates better than any other the mistake of laying brick in streets of heavy traffic.

The writer collected a number of bricks from Carpenter St., W. 17th St., La Salle St., and Halsted St. during the summer of 1904, at times when openings were made in the pavement for gas connections, repairs along the rail and renewals. No effort was made to secure the worst specimens; they were taken from the pile in the street after the opening had been made. Table II shows the size and weight of these specimens, as well as the calculated loss in the time they were in the pavement. This loss was secured by getting the weight of the original block from the size and specific gravity of the material, the assumption being made that the blocks were square cornered and each set was of uniform density.

— TABLE II —

STREET	Brick No.	SIZE	Weight lbs.	Spec. Grav.	Wt. Orig. Brick	% Loss
Carpenter St. laid in 1899 Built by Gaffney & Long Const Co Paving $1.85 per sq. yd.	1	8″ × 2 5/8 × 3 13/16	6.62	2.45	7.07	6.2
	2	8 × 2 5/8 × 3 13/16	6.14	″	7.07	13.1
	3	8 × 2 5/8 × 3 13/16	6.43	″	7.07	9.0
	4	8 1/4 × 2 5/8 × 3 13/16	6.56	″	7.26	9.6
	5	″ ″ ″	6.75	″	7.26	7.0
	6	8 1/8 ″ ″	6.37	″	7.15	10.8
	7	8 3/16 ″ ″	6.62	″	7.17	7.6
W. 12th Street laid in 1899 Built by Jas. A. Sackley Paving $1.89 per yd.	1	8 3/16 × 2 5/8 × 3 13/16	6.96	2.41	7.12	2.1
	2	″ ″ ″	6.81	″	″	4.3
	3	″ ″ ″	6.94	″	″	2.6
	4	″ ″ ″	6.87	″	″	3.4
	5	8 1/16 × 2 3/4 × 3 3/4	6.75	″	7.22	6.5
	6	8 1/8 × 2 3/4 × 3 13/16	6.76	″	7.39	8.2
LaSalle St. laid in 1895	1	8 × 2 1/4 × 3 5/8	5.13	2.43	5.71	10.2
	2	″ × 2 5/16 × ″	4.63	″	5.87	21.2
	3	″ × ″ × ″	5.37	″	5.87	8.4
	4	″ × 2 3/8 × ″	5.50	″	6.03	8.8
	5	7 7/8 × 2 5/16 × ″	5.06	″	5.78	12.4
	6	″ × ″ × ″	5.00	″	5.78	13.5
	7	8 × 2 3/8 × ″	4.75	″	6.03	21.2
	8	7 7/8 × 2 5/16 × ″	5.18	″	5.78	10.2
Halsted St. laid in 1899. Built by R.F. Conway Co. Paving $2.10 per yd.	1	8 3/16 × 2 5/8 × 3 11/16	6.56	2.49	7.07	7.2
	2	8 × 2 5/8 × 3 3/4	6.43	″	7.06	8.9
	3	″ × ″ × 3 13/16	6.18	″	7.18	13.9
	4	″ × 2 9/16 × 3 13/16	6.25	″	7.01	10.8
	5	″ × 2 11/16 × ″	6.87	″	7.35	6.5
	6	″ × 2 5/8 ″	6.14	″	7.18	14.7
	7	″ × ″ × 3 11/16	6.31	″	6.95	9.2

— PAVEMENT FOUNDATIONS —

PRESENT METHOD OF CONSTRUCTION

In preparing the subgrade all the necessary filling to bring the roadway to the required grade is made before the curb is set. Where the curb consists of a limestone or sandstone slab, a berm four feet wide, level with the top of the curb, is provided back of it to form a brace and prevent any lateral motion or displacement of the slab. Beyond the berm and back of the curb the backing earth is sloped 1½ horizontally to 1 vertically. This condition obtains only where it is necessary to fill to fill in order to bring the street to grade. Where a cut is necessary no berm or slope is necessary; but when the contractor finds it necessary to borrow from the earth back of the curb he must leave that portion level with the top of curb for at least four feet back of the curb.

Where the street surface requires cutting to bring it to the necessary subgrade, the earth must be excavated to a depth sufficient to bring the roadway to the proper subgrade after having been thoroughly compacted. In no case should the earth be plowed below the subgrade. In the event that spongy material or other inferior or vegetable matter is encountered in the roadway, this must be removed and the

surface brought up to the necessary grade with substantial filling either in the form of cinders or earth, and must be deposited in layers not exceeding two feet in thickness, after which it must be thoroughly compacted by rolling with a roller not less than ten tons in weight. The specifications make the further stipulation, "that the contractor bid with the express understanding that he must use all necessary precautions in preparing the subgrade so as to support the pavement permanently, and so that the pavement shall remain at the original grade for a period of ten years. This clause will not be waived on account of any trenches or holes made in the street, prior to the laying of the pavement, by any corporation or private party".

Approaches connecting the street with unimproved streets or intersecting alleys must be provided with "headers" extending from curb to curb. These headers are made of oak planks 3"x12" supported by 6 inch split cedar posts, three (3) feet in length, firmly set in the ground and spaced no more than five (5) feet center to center. Back of the header, and in the direction of the unimproved street or alley the earth is cut or filled as the circumstances demand, so that the slope of the approach does not exceed one in twenty. The approaches must be well compacted to prevent any settlement of the adjacent pavement. This latter

requirement relative to slope of approach is only approximately approached, however, in districts thinly populated and where the roadway level is several feet above the elevation of the surrounding land. The failure to comply with the specifications in this particular, is due to a lack of earth to secure a grade of one in twenty where fill is necessary. In many instances which came to the writer's notice, the grade approaches more nearly three in twenty than one in twenty. But failures in pavements where this violation occurs, seldom arise from that feature or defect, if it may be called so. A rigid adherence to the specifications is not essential in such districts where the violation exists at present. In those districts where the slope does not comply with the specifications, the pavements are mostly cedar block and the traffic is much less than that necessary to crowd the pavement out of place at the approaches. Long before any tendency to crowd toward the approach slope develops the pavement is too far gone in rot and failure cannot be attributed to insufficient approach embankment.

Upon the finished subgrade a concrete foundation six inches thick is laid. During the last few years portland cement was used in the foundations. The great varieties in the densities

of materials used in filling in the streets prepara-tory to paving convinced the authorities that something more substantial than planking was necessary to support the pavement even though constructed of wood blocks. Uncemented stone resembling macadam con-struction was used to replace planks and it was used in the foundation for granite block pavements. Subsequently natural cement was used in pave-ment foundations till 1892 when the use of portland cement was advocated and later used. Several pavements which were torn up by gas companies during the summer of 1904 came under my obser-vation, and they showed that those foundations made with natural cement showed little if any binding qualities. In most cases the natural cement concrete was damp and easily excavated with a pick. The cements now used must conform to the following general specifications:-

Fineness "It must be so ground that 92% will pass thru a standard number 100 sieve having 10,000 meshes per square inch."

Soundness "The cement must meet the requirements of the boiling test".

Setting "The cement when mixed with 20% of water by measure shall take initial set in

not less than 45 minutes".

Strength. "Briquettes, one inch in cross section shall develop the following ultimate tensile strength":-

Neat:- one day in air and six days in water four hundred pounds.

One part cement to three parts sand, one day in air and six days in water, one hundred seventy five pounds, and shall show a gradual increase in strength of fifteen percent at the end of twenty-eight days."

Sand now used. The sand commonly used in the foundation concrete is known as torpedo sand. It is specified that it "shall be clean, dry, free from loam, dust and dirt, of sizes ranging from one eight of an inch down to the finest and in such proportion that the voids determined by saturation shall not exceed 33% of the entire volume and it shall weigh not less than one hundred pounds per cubic foot". Actual samples taken from work in progress during the summer of 1904 show a mesh composition as follows:-

MESH COMPOSITION OF TORPEDO SAND						
Sieve number	200	100	74	50	30	20
% Passed	1.2	4.2	14.8	38.5	10.5	10.8
% Retained						19.4
% Voids -------- 29.6						

CURB AND GUTTER

Preliminary Previous to surfacing the subgrade the engineering department of the city establishes the grade of the curb which is a means of establishing the street grade for at all points the crown of the pavement is parallel to the top of the curb. This grade also furnishes a basis for all measurements during construction. Grade points are established at street intersections and at points midway between intersections, or more frequently if the blocks are long. These points are usually marked on lamp posts, telephone poles, etc, or any other fixture which is not liable to removal during construction; and are placed a couple of feet above established grade to render them more readily distinguished by the curb builders.

The line of the street is also given by an offset a few feet inside the curb line, the latter being located by measuring from this offset line the specified number of feet. Where the side walk is a permanent one such as limestone slab or concrete, the line is established on it by making indentations in it every one hundred feet or more. Following the preliminary the engineer furnishes the contractors with a profile of the street under improvement

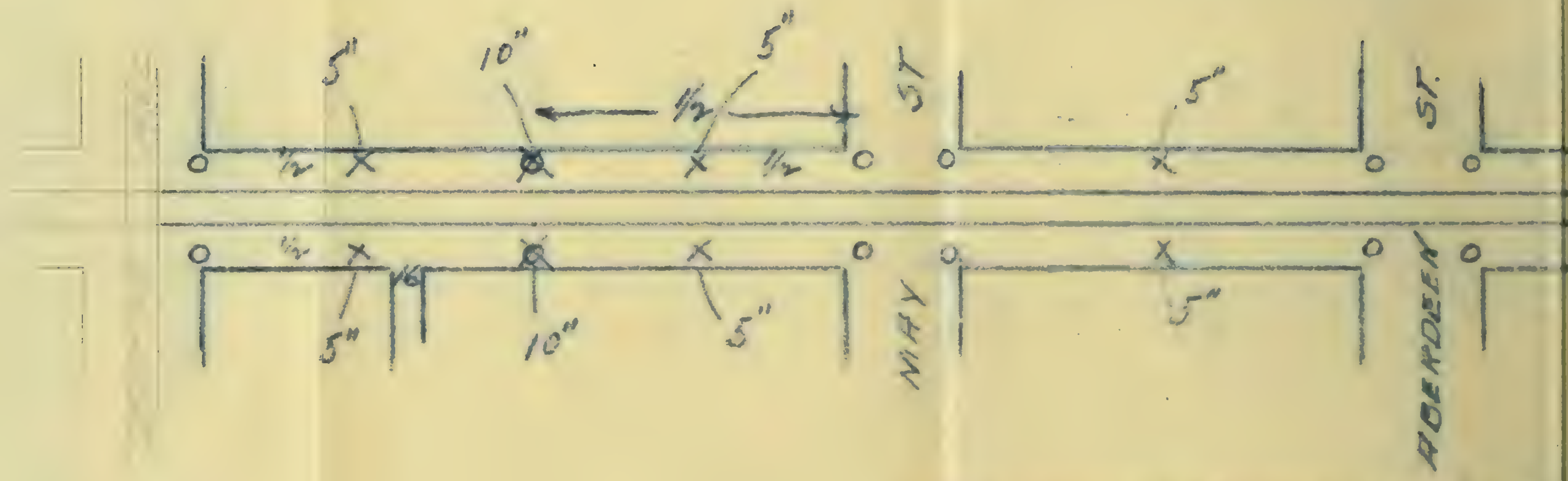
Profile

from St. Ry. on E

(B.T.

Er. Miller St, M

M



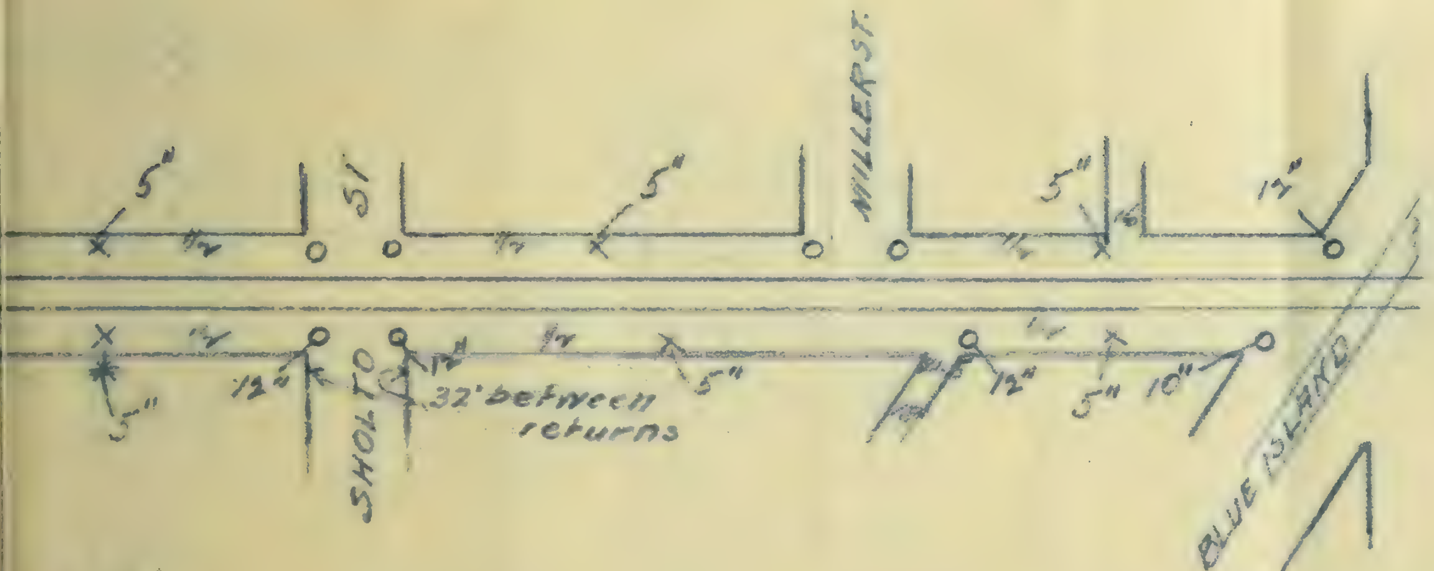
LINE MARKS - are 10' N of c

GRADE " " 2' abov

Roadway 38' Crown

Return alley curbs wi

ot Taylor St.
Island Av. to St. Ry on Paulina St
land to Center Av.)
of Sholto St., Aberdeen St.,
y St. & Centre Ave.



rb line

to street railway tracks
after same are brought to grade.
out gutter flags 24" deep.

June 8th 1904
E.W. Willard
Chief Engr.

Between
pages 105-106

showing the location of the line, width of roadway, position of inlets, crown of roadway at the various points, manholes etc. The attached carbon copy is representative of the profiles furnished and is self explainatory. It is a profile for West Taylor St. between Blue Island and Centre Avenues, which was paved with sheet asphalt during the summer of 1904.

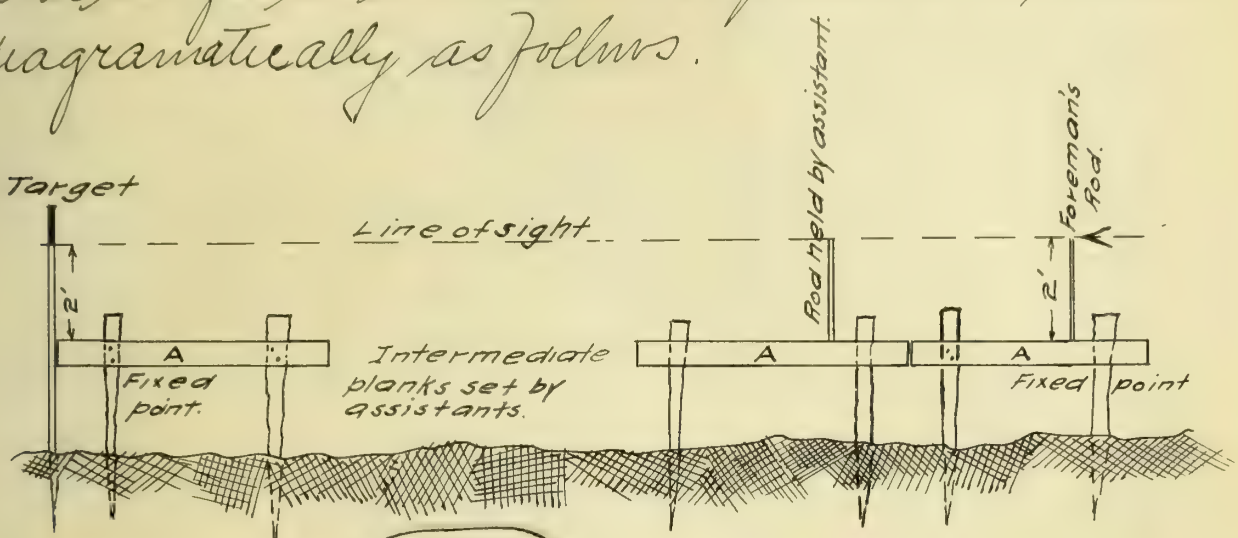
Foundation. With the establishment of grades and line and prior to grading the pavement sub-grade, a trench is excavated along the line of the curb. The trench is usually four to six inches wider than the combined curb and gutter base, and a layer of cinders from five to six inches deep is placed in this, sprinked and tamped and forms the bed upon which the concrete is laid for the curb and gutter.

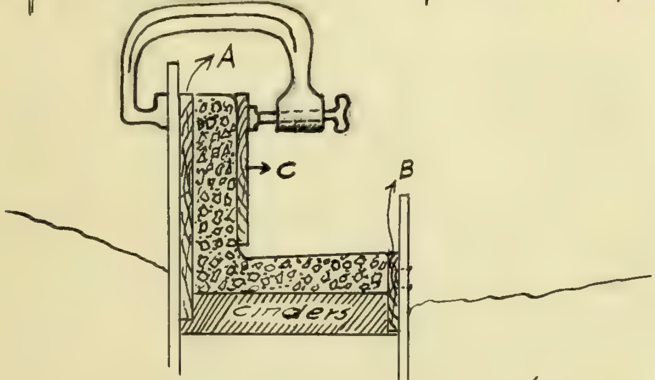
Forms. Where the combination curb and gutter construction is employed, the setting up of the forms closely follows the tamping of the cinder bed. In many instances, however, the forms are placed before the cinder bed is tamped. The latter method results in a greater economy in the amount of cinders used. This is accomplished because the front and back boards of the forms are placed immediately after excavating the

trench and the cinders are placed and tamped within the limits of the forms.

The method of setting up the forms is as follows:- For a gang of twenty one men exclusive of superintendant and city inspectors, and such as was used in curb and gutter construction in Clifton Park Ave, three men, consisting of a forman and two helpers, are ample to set up all the forms. A line of long stakes made from any available two inch planking, is driven at the specified distance from the offset line forming the line of curb. Upon these stakes are nailed two inch planks which are brought to the grade of the curb and form the backing of the curb form. In bringing the planks up to the grade, the forman first places those immediately adjacent to the established benches and then places the intermediate backing planks by sighting from one fixed point to the other and thus securing a uniform grade from one bench to another. This is generally accomplished by erecting a temporary foresight target at the backing board adjacent to an established bench and a few feet above grade, or equal to the height of a straight edge which the forman uses to sight over from the next fixed backing board. The intermediate back-

-ing planks are nailed to the stakes by assistants while the foreman adjusts them to grade by sight-ing over his straight edge resting on one fixed board to the target at another. The process is shown diagramatically as follows.





After placing the backing boards (A) the front boards (B) are placed at a distance from A equal to the curb thickness plus the width of the gutter flag. These too are held in place by stakes and are so graded that the fall in the gutter toward the inlets is as prescribed in the profile. Their elevation is fixed by measuring down from the backing boards, already fixed.

Boards A and B are the only ones which are placed by the form builders, and these are nailed securely to the stakes. The board C forming the front of the curb, is placed by the concrete laying gang after the gutter flag is well rammed. It is held in place by means of clamps placed at frequent intervals along its length. The spacing between the front and back curb boards (A and C) is obtained by placing a metal disc of the exact thickness of the curb in width between them, the clamps holding the discs in place by the bearing of plank C upon them as the clamps are screwed tight. These spacing discs are re-moved as soon as the concrete is tamped suf-ficiently to bear the plank C without allowing it to tip toward the curb.

Concrete The curb and gutter is made of concrete formed by mixing one part of Cement with two parts of fine granite screenings and four parts of crushed granite, mixed with just enough water to cause a film of moisture to appear on top after ramming in place. It is mixed by hand on a sheet metal board. The exposed surfaces are covered with a finishing

coat of mortar 3/8 inch thick composed of one part cement to one and one half parts of fine granite screenings. This covering of mortar is placed over the gutter flag and top of curb while the facing board C is still in place. To bring the mortar coat to a uniform thickness over the gutter flag, metal strips equal in thickness to the prescribed thickness of the mortar coat, are placed at intervals of eight to ten feet in the gutter and the mortar is brought to place by means of a wooden template which is worked to and from the curb till the mortar coat is uniform in surface. The metal strips are then removed and the surface is trowelled. The mortar coat on top of the curb is brought to an even surface by working a wooden trowel over the curb between the boards A and C. The preliminary finishing as above described is done by one man. Following this rough finishing the board C is removed and a second man trowels both curb and gutter flag to a smoothe surface with a steel trowel and gives the corners the specified curvature. The face of the curb after removing the front board C is finished by sprinkling it moderately with water by means of a brush and then throwing

dry cement on this "moistened" surface. The cement thus thrown on the face clings to it, filling the interstices of the concrete and forms the mortar necessary to give it a smoothe surface after trowelling. The whole exposed surface is finally gone over with an ordinary dust brush in a direction at right angles to the length of the curb and gutter, giving the whole a rougher appearance than is obtained by the use of metal trowels.

The crushed granite used in curb construction is a Wisconsin granite of a dark brown color, the stone particles varying in size from 1/4 to 1 inch in greatest dimension; and the percent of voids of the crushed stone averages 41%. The following shows the mesh composition of the crushed granite screenings.

Mesh Composition of Granite Screenings						
Sievenumber	100	74	50	30	20	200
% Passed	4.7	7.5	9.2	8.2	2.0	6.0
% Retained	—	—	—	—	62.4	—
% Voids - - - 30						

TABLE I
SHOWING MILES OF PAVEMENT LAID EACH YEAR
and Percentage of Wood Block

YEAR	WOOD BLOCK	GRAN. BLOCK AND MED. STONE	MAC-ADAM	GRAVEL AND CINDER	OAK PLANK	ASPH. BLOCK	SHEET ASPH.	BRICK	WOOD BLOCK % TOTAL
1880	13.68	0.20	2.49	0.34 G	0.20	—	—	—	80
81	18.20	0.58	6.14	—	—	0.07	-	—	72
82	17.60	1.24	5.25	—	—	1.38	0.21	—	69
83	16.00	2.50	1.00	—	0.25	—2.75—		—	71
84	27.24	3.29	2.69	—	—	0.30	1.00	—	78
85	30.47	1.73	4.55	0.36 c	0.11	0.07	0.89	—	79
86	39.91	1.75	1.35	0.19 G	0.27	0.28	0.18	—	90
87	31.13	2.85	1.91	0.49	1.56	0.25	0.22	—	81
88	47.15	3.04	3.67	—	0.47	—	—	—	86
89	62.75	5.68	38.45	—	—	—	0.80	—	58
1890	75.72	1.27	21.40	—	—	—	0.95	0.38	75
91	73.83	0.36	37.21	Burnt clay 0.23	1.24	—	4.43	0.29	62
92	77.22	0.63	27.20	—	—	—	2.92	—	71
93	101.67	0.85	30.50	—	—	—	4.02	0.42	74
94	63.54	4.66	15.19	—	—	—	8.34	0.22	69
95	28.62	1.16	9.35	—	—	—	5.76	2.86	59
96	43.77	3.56	13.60	—	—	—	17.01	4.71	53
97	23.53	0.53	15.52	—	—	—	10.38	6.08	42
98	18.82	6.52	0.62	—	—	—	8.52	1.70	52
99	10.30	1.43	8.79	Slag 3.80	—	—	11.91	13.01	20
1900	10.76	1.47	20.94	—	—	—	20.66	17.64	15
01	2.26	2.25	19.65	—	—	—	6.65	8.01	5.8
02	2.58	4.57	25.69	—	—	—	22.60	11.36	3.8
03	1.92	3.55	20.15	—	—	Rock Asph 0.18	48.88	7.06	2.3
04	Creo. Blk 0.66	4.5	27.33	—	—	—	42.00	5.5	0.82
					—				

— TABLE III —

MILEAGE AND PERCENTAGE OF EACH KIND OF PAVEMENT. - 1900 to 1904 INCLUSIVE										
KIND	1900		1901		1902		1903		1904	
	Miles	%	Miles	%	Miles	%	Miles	%	Miles	%
Sheet Asph.	100.29	7.57	106.94	7.96	129.54	9.0	177.45	12.69	220.0	15.31
Block Asph.	2.43	0.18	2.43	0.18	2.43	0.18	2.43	0.18	2.28	0.16
Brick	48.83	3.69	56.84	4.22	68.20	4.97	75.26	5.38	80.78	5.61
Cedar Blk.	749.40	56.59	735.82	54.76	708.43	51.75	663.35	47.42	625.42	43.50
Foundation	1.08	0.08	1.08	0.08	—	—	—	—	—	—
Granite	29.80	2.18	31.05	2.31	35.42	2.58	38.64	2.76	43.25	3.01
Medina Stone	2.29	0.17	2.29	0.17	2.29	0.16	1.74	0.12	1.45	0.10
Slag	3.80	0.23	3.80	0.28	3.80	0.23	3.80	0.27	3.80	0.26
Macadam	387.08	29.25	403.69	30.04	420.73	30.69	435.80	31.15	457.63	31.83
Creosoted Block	—	—	—	—	—	—	0.03	—	0.60	0.04
Novaculite	—	—	—	—	—	—	0.28	0.02	2.01	0.14
Rock asphalt	—	—	—	—	—	—	0.18	0.01	0.57	0.04

AMOUNTS LAID IN 1904 - Cost $3,581,038.00		
KIND	MILES	%
Sheet Asphalt	42.00	52.50
Granite Block	4.50	5.63
Brick	5.50	6.87
Macadam	27.33	34.17
Creosoted Block	0.67	0.83
Total	80.00	100.0